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THE CHARACTERIZATION AND ANALYSIS OF ORNAMENTAL CAST STONE AND STUCCO FROM THE PALACIO ERRÀZURIZ, BUENOS AIRES, ARGENTINA

James Valente Banta

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1.0. INTRODUCTION

The focus of this thesis has been the study and characterization of the exterior masonry materials of the Palacio Errazuriz (now the National Museum of Decorative Arts) in Buenos Aires, Argentina. By utilizing a combination of approaches and techniques including archival research, forensic architectural investigation, and materials analysis, an attempt was made to determine the original and subsequent appearance of the building over time; and to prepare general recommendations for conservation. This work was undertaken at the request of the architectural firm of Baez, Carena, and Grementieri as part of a project preparation grant funded by the Getty Grant Program.

The Palacio Errazuriz was designed by French architect René Sergent (1865-1927) and constructed between 1911 and 1918 by the Buenos Aires-based builders, Lanus y Hary. The building is complex in terms of its design precedents and construction technology as it was designed by a French architect who never traveled to Argentina and built in a country of diverse cultural and economic influences. The French neo-classical exterior is constructed of a combination of masonry materials: cast stone, stucco, and natural stone while the interior is a rich mixture of neo-classical, medieval, and moderne elements.

The exterior of the building has changed appearance over time through soiling, over-painting, and discoloration. Environmental factors and questions of manufacture have also played an important role in the deterioration of the facade masonry; some of the cast stone is failing and has detached from the building due, in part, to the corrosion of the embedded reinforcing bars. In 1978, the building was mechanically cleaned by sandblasting which may also have effected the weatherability of the exterior surfaces of the building.

As with all buildings, there is a direct relationship between the intended appearance of the Palacio and the specific use of natural and artificial materials. Natural

limestone is mostly employed on the principal facade in the colossal Corinthian portico with its pedimental sculpture. Cast stone elements, intended to imitate the appearance of the natural stone, are used everywhere, especially on the secondary facades, for economy. Stucco on the exterior of the Palacio is scored to resemble masonry and the presence of colored fines in the mixture suggests that it was never painted and was intended to resemble the natural limestone on the building.

At the time the Palacio was built, the United States and Europe were developing new technologies for the fabrication of cast stone and had begun to establish standards for its manufacture and use. An important aspect of this study of the conservation of the Palacio is knowledge of the technology employed in its construction and in particular an understanding of the use of cast stone masonry on the building.

Cast stone is a subject that has lacked attention in the technical and art historical literature. Many early cast stone buildings are approaching an age when problems of maintenance and conservation are more relevant and the Palacio Errazuriz offers a great opportunity for the close study of this important material.

Significant in the research and execution of this thesis was the use of analytical techniques, and in particular Differential Thermal Analysis (DTA), to obtain information about the composition and type of binders used in the cast stone and stucco from Palacio Errazuriz.[1]

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[1] The only closely analogous application of DTA was in the examination of ancient mortars [Giacomo Chiari, Maria Laura Santarelli, and Giorgio Torraca, "Caratterizzazione delle malte antiche mediante l'analisi di campioni non frazionati," *Materiali e Strutture: Problemi di Conservazione 2* (1992): 111-137]. Another related application of DTA was for mortars from gothic churches [J. Adams, D. Dollimore, and D. L. Griffiths, "Thermal Analytical Investigation of Ancient Mortars from Gothic Churches," *Journal of Thermal Analysis 40* (1993): 275-284]. In the former study, the authors combined Thermal Analysis with other analyses to provide information on the general characteristics of mortars for the purposes of conservation. In the latter study, the authors sought to demonstrate that old mortars, despite having recarbonated, remain soft and incompatible with modern cementitious mortars. Adams et al used Thermal Analysis to learn the proportions of hydrated lime and gypsum in their mortar samples.

1.1. Methodology

The techniques used in the examination and analysis of the samples range from the simple to the complex. Examination of forty (40) samples of the exterior masonry (taken by the project architect, Fabio Grementieri) was undertaken to document and classify the different facade materials employed on the building. Examination began with gross visual observation of the samples using stereo optical microscopy for the purposes of general classification. After gross visual classification of the samples, further characterization was undertaken to by cross-sectioning embedded representative samples and examining them under reflected light stereo optical microscopy. Physical characteristics such as layer structure were described using conventional methods and color was identified using the Munsell Soil Color Chart.

Further qualitative and quantitative analyses were conducted to determine composition, methods of manufacture, original appearance, and deterioration. Gravimetric analysis of representative samples was performed in order to obtain basic information about the components in the mixtures. Representative samples that were characterized in the initial examination were thin-sectioned for transmitted light microscopy. Thin-section examination provided information regarding the microstructure of the cast stone and stucco, such as the layer structure; porosimetry; particle type (mineralogy), size, shape, and occurrence.

Findings were confirmed with the aid of Scanning Electron Microscopy (SEM) which was helpful in further understanding the morphological features and in conjunction with Energy Dispersive X-ray Analysis (EDX), elemental composition. Differential Thermal Analysis (DTA) was used to identify compounds and their percentages within the sample. Differential Thermal Analysis coupled with Mass Spectrometry provided information regarding elements and compounds present, and proved to be very helpful in analyzing these samples.

A review of the available literature on cast stone provided much of the historical context for studying building technology. Research using early trade journals, catalogues, and publications was particularly significant in this respect. General questions posited for characterization and analysis of samples were:

- What are the facade materials on the building?
- How many types of materials were used?
- What is the relationship between the materials and their usage on the building?
- What is the composition of the materials?
- How did the materials originally appear?

2.0. ARCHITECTURAL DESCRIPTION OF THE PALACIO ERRAZURIZ

The Palacio Errazuriz was designed in 1911 as a grand residence for Matias Errazuriz, a wealthy citizen of Buenos Aires whose tastes reflected the francophilia of Buenos Aires during the early twentieth century. The Palacio Errazuriz was designed by Sergent after the 18th century French *hotel de ville* utilizing the principles of the Ecole des Beaux Arts which emphasized classical composition and symmetry. (see Appendix 13.1)

The Palacio is constructed of brick masonry and metal frame clad with a skin of stucco, cast stone, and natural stone ornaments. The building is two stories high with a raised basement and a steep, low mansard roof. Plain ashlar masonry and a plain water table characterize the basement. (see Illustrations 1 and 2)

The pediment is adorned with figurative sculpture flanked by two sculpture groups that rest on bases above the cornice. The entablature has an enriched architrave and frieze with a cornice comprised of scroll consoles and rosettes on a paneled soffit.

The main facade (north), which faces the Avenida del Libertador, has nine bays total with a central porticoed pavilion with side-wings. There are three arched openings under the portico on the first story and three corresponding rectangular openings on the second story. The colossal order columns are fluted with composite capitals and plain pedestals. In front of the portico is a terrace framed by an ornamental stone wall that circumscribes the property. The stone wall is surmounted a tall wrought iron fence with cast bronze ornament. The portico platform is accessed by the east and west, from the side entrance to the property or the garden, respectively. (see Illustration 3)

On the first story, the hyphens between the portico and the side-wings contain a single apsidal niche detailed with a shell half-dome. The first story windows on the side-

wings have pierced guilloche pattern railings on the shallow balconies or balconettes and are enriched with two moldings of foliated cast stone ornament. The window architraves are eared with straight rectangular hoods enriched with foliated egg and dart and dental moldings made of cast stone. There are two cast stone pine cone pendants on both sides of each window lintel. The first story windows in the portico are arched and enriched with a foliated archivolt and a scroll keystone. The archivolt is ornamented with a laurel leaf garland and water-leaf molding. All the openings are fitted with original moveable metal louvered shutters. The windows all have wooden casements.

The rectangular second story windows do not have eared architraves and are enriched with a single foliated molding. Second story stone sills are supported by cast stone triglyph consoles adorned with festooned drapery. Window over-lintels are ornamented with cast stone ribboned laurel leaf festoons. The hyphens between the portico and the side wings feature roundel windows adorned with the same laurel leaf garland and the same sill with consoles and festooned drapery.

The west facade, which faces the garden and Sanchez de Bustamante, has five bays and is similar in detail to the north facade, but has pilasters instead of columns. (see Illustration 4) There is a raised terrace with balustrade to match the balconettes of the main facade. The 1940s addition to the building mirrors the west facade and is adjacent to the original structure at the southwest corner. (see Illustrations 5 and 6)

The east facade, which faces Pereya Lucena. is the current entrance to the building. (see Illustrations 7 and 8) The building projects outward on the east facade culminating in a tholos porte-cochere. The ornament and details of the east facade are similar to that of the other facades. The attached columns that compose the porte-cochere rest on plain bases and are not fluted. The columns are crowned with Doric capitals and support a plain entablature. There are blind roundel windows on the projection of the east facade that are surmounted with laurel leaf garlands. The diagonal where the east facade projects outward is enriched with crossed and tied olive branches in a bas-relief panel.

3.0. NATURAL STONE AT THE PALACIO ERRAZURIZ

There are three different types of natural stone used on the building which all appear to be limestones. Two of the stones are clearly identifiable as limestone because of the presence of biomorphs left behind from the time when the rock was formed. These fossils are testimony to the origins of a limestone rock. Examination of the natural stone samples provided a reference for understanding the intended appearance of the cast stone.

One type of limestone is used for the columns and pedestals on the building's north facade. It can be characterized as a medium-grain fossiliferous limestone that varies in color from off-white to buff or tan. (see Illustration 9) There is some evidence of tooth-chiseled tooling marks as well as bush-hammered surfaces on the elements carved from this stone, but most surfaces are honed, such as the columns.

A coarser-grained fossiliferous limestone is used for the socles on which the columns on the north facade rest and matches the columns in color and overall appearance. This stone is the same used for the figurative sculpture on the building. (see Illustration 10) Few tooling marks remain on this stone due to its intrinsic coarseness and erosion from weathering, but there are traces of tooth-chiseling in areas that are relatively sheltered, such as under the arm of a figure.

The third stone is a slightly pink fossiliferous limestone that is figured with bioturbation and stylolytes or natural joints within the matrix of the stone itself. (see Illustration 11). This stone was used for the steps, watertable, and some of the masonry that comprises the central porch on the north facade.

4.0. CAST STONE AT THE PALACIO ERRAZURIZ

Natural stone was used on the primary facade in conjunction with cast stone in areas and elements of secondary importance. Cross-sections of the cast stone revealed the presence of a variable colored aggregate with a pigmented cream or tan colored paste. This gives further evidence of the analogous relationship between the cast and natural stone.

Cast stone is often used as an economical substitute for natural stone, and in many cases, complements natural stone features of a building. This was true of the Palacio Errazuriz, where both natural and imitative materials are coordinated to appear as one uniform material.

There are four types of cast stone elements on the exterior of the Palacio Errazuriz which are characterized by their mixtures and their apparent methods of manufacture. However, despite the variation in mixture or method of manufacture that is visible in cross-section examination, the overall effect appears to have been the suggestion of a monochromatic limestone exterior. Cleaning tests using ProSoCo Heavy Duty Restoration Cleaner™ revealed a cast stone surface that is lighter than the present soiled tan or light brown/yellow appearance. The cleaned cast stone surface appears to match the natural limestone well and offers strong evidence that the individual cast stone elements was intended to resemble the limestone. (see Illustration 12) The occurrence of a slightly variegated, but generally monochrome surface appearance is significant for the subtlety and artistry achieved in the cast stone to create a lively chromatic appearance that truthfully imitates the slightly variegated surface of the limestone. (see Illustration 13)

Many samples exhibit fine surface cracks which are characteristic of Portland cement castings (Millar 285). These cracks occurred during the setting of the cast stone, probably due to an excess of water in the mixture. Given the characterization of the samples and the date of construction coupled with the period in the development of the

cast stone industry, it is likely that the binder in the cast stone mixtures consists of a combination of white Portland cement and lime. (see Differential Thermal Analysis, Chapter 9.4)

The presence of one homogeneous mixture in many of the samples may be evidence of the wet cast process. Other samples are composed of two mixtures, a facing and a backing, which may suggest the dry process of casting.

There is evident corrosion of the reinforcing bars that are embedded within the cast stone. (see Illustration 14) Another factor that has led to the deterioration of the cast stone elements may be freeze-thaw cycling.

5.0. STUCCO AT THE PALACIO ERRAZURIZ

The scored stucco on the exterior of the Palacio was also probably intended to match the appearance of the natural limestone on the building. (see Illustration 13) The presence of variable colored fines in the stucco indicates that it was probably never painted. The scored courses are approximately 15 inches long and vary in horizontal dimension. The stucco is combed with a serrated float sometimes in perpendicular or crossed directions creating an appearance of chiseled or bush hammered stone. The presence of bush hammered limestone socles may have provided the reference for the surface treatment of the stucco.

The stucco is a two-layer structure with a base or scratch coat of approximately 1/2 inch to 3/4 inch thick and a finish coat that is approximately 1/8 inch thick and much finer in texture and whiter in color than the base layer.

6.0. GLOSSARY OF EXISTING EXTERIOR MASONRY CONDITIONS

The following illustrated glossary was established as a method for defining and documenting existing conditions of the exterior masonry materials on the building. These conditions are symptomatic of deterioration mechanisms and/or weathering.

6.1. Natural Stone

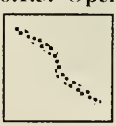
6.1.1. Cracking (0.1 mm - 5.0 mm)

Fractures of variable length, width, depth, and orientation.

6.1.2. Cracking (> 5.0 mm)

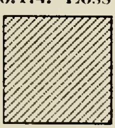
Fractures of variable length, width, depth, and orientation.

6.1.3. Open and Defective Joints



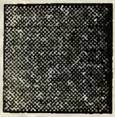
Complete or partial loss, cracking, or separation of mortar within stone joints.

6.1.4. Loss



Absence of original material as judged by incompleteness of form or decoration.

6.1.5. Soiling



Surface deposition of black accretions attributable to atmospheric pollution and/or organic microflora.

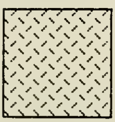
6.1.6. Erosion

Active detachment of grains resulting in a roughly textured, granular appearance and increased surface area. Often in association with areas of severe exposure and moisture.

6.1.7. Exfoliation

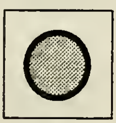
The detachment and often partial loss of one or more surface layers of stone parallel to each other and in association with bedding and stone orientation.

6.1.8. Paint Failure



Previous and active deterioration of paint, observed as blistering, flaking, cracking, and loss, usually in association with water infiltration.

6.1.9. Previous Repairs



Subsequent alterations made for structural, aesthetic, or functional reasons including painting, mortar in-fill and adhesive repair of losses, cracks, and original openings.

6.2. Cast Stone

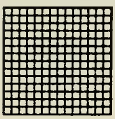
6.2.1. Cracking (0.1 mm - 5.0 mm)

Fractures of variable length, width, depth, and orientation attributed to the internal disruptive pressures of corroding metallic reinforcements and anchors.

6.2.2. Cracking (> 5.0 mm)

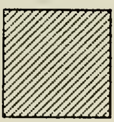
Fractures of variable length, width, depth, and orientation attributed to the internal disruptive pressures of corroding metallic reinforcements, anchors, and structural movement.

6.2.3. Incipient Spalling



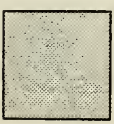
Shallow, irregular detachment associated with the corrosion of internal metallic reinforcement and anchors. Incipient spalling often leads to cracks and losses.

6.2.4. Loss



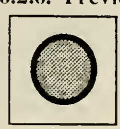
Absence of original material as judged by incompleteness of form or decoration; often in association with incipient spalling and cracking.

6.2.5. Erosion



Active detachment of grains resulting in a roughly textured, granular appearance and increased surface area. Often in association with areas of severe exposure and moisture.

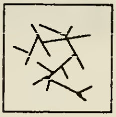
6.2.6. Previous Repairs



Subsequent alterations made for structural, aesthetic, or functional reasons including mortar in-fill and adhesive repair of losses, cracks, and original openings.

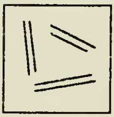
6.3. Stucco

6.3.1. Map Cracking



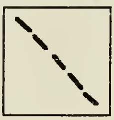
A network of fine cracking of variable length and orientation within the finish coat of stucco. This condition usually occurs within confined surface areas suggesting restriction during thermal expansion.

6.3.2. Linear Cracking



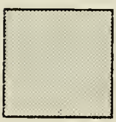
Fractures of variable length, width, depth, and orientation. Linear cracking is usually due to structural movement or may relate to the corrosion of internal metallic elements used for reinforcement or reattachment.

6.3.3. Edge Cracking



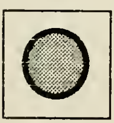
Variable detachment occuring at the interface between cast stone elements and stucco.

6.3.4. Erosion



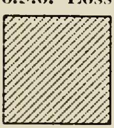
Active detachment of grains resulting in a roughly textured, granular appearance and increased surface area. Often in association with areas of severe exposure and moisture.

6.3.5. Previous Repairs



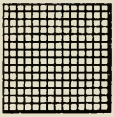
Subsequent alterations made for structural, aesthetic, or functional reasons including mortar in-fill and adhesive repair of losses, cracks, and original openings.

6.3.6. Loss



Absence of original material as judged by incompleteness of form, decoration, or layers.

6.3.7. Incipient Spalling



Shallow, irregular detachment associated with the penetration of water. Incipient spalling often leads to cracks and losses.

7.0. HISTORY OF CAST STONE

To better understand the appearance and construction history of the Palacio, research of the construction materials and techniques was undertaken especially as related to the manufacture and use of cast stone. Although there is little information in the United States on nineteenth and twentieth century Argentinean building technology, some research exists on the study of early cast stone manufacture in North America and Europe. The use of artificial or cast stone dates to ancient times, but there was a rapid development of the industry in the late nineteenth and early twentieth centuries. Many early cast stone patents were developed in the United States, England, and France. Among them was the "System Coignet" patented by Frenchman François Coignet in 1867 and sold to the New York Stone Contracting Company where it received a U.S. patent in 1869. (Chamberlin 22) Other examples included the Sorel patented cast stone manufacturing process — originally French — then sold to the Union Stone Company in Boston in the 1860s. Also among these early cast stone products were Frear stone, patented in 1868 and Ransome stone, patented in 1872.

Early cast stone received mixed reviews by critics of architecture and construction, as well as by architects and engineers themselves. There was an effort aimed at popularizing cast stone as a form of masonry that could be used in a variety of ways at low costs (relative to natural stone) and adapted to different requirements. In dealing with the economic difficulty of an ornamental masonry facade, cast stone was heralded as an affordable solution that replaced the expense of natural stone without sacrificing its appearance.

Cast stone can be defined as a fine or decorative cementitious composite often made to resemble natural stone. In its basic form, cast stone consists of aggregate (sand and/or crushed stone), binder (cements — artificial or natural — and/or lime), and water. Sometimes additives such as pigments are added in order to better achieve the desired

appearance in the product. Cast stone was manufactured as structural units, ornamental forms, or monolithic castings.

Cast stone often simulated cut or sculpted stone and could be tooled or finished in the same manner as natural stone. The advantages of cast stone over natural stone were quickly appreciated in terms of economy of time to make a mold and an infinite number of casts, versus the time it takes to quarry, ship, and carve a natural stone element.

However, early cast stone was not immediately accepted for what it truly represented. The material was immediately popular for its economy, but was doubted for its structural strength and criticized for its dishonesty as there was an intrinsic stigma attached to it due to its ability to resemble natural stone. This "curse" of imitation was often a topic of discussion among those writing about the industry at the time. In 1905, a writer in an early issue of *The Cement Age* stated:

> I would that we might rather embrace the thought of concrete as a union of certain elements scientifically combined to form a material useful in construction because of its own distinctive merits, and not because of its resemblance to any other natural or artificial product. I am convinced that the effort toward imitation has caused half of the evils in connection with concrete construction. If we take it for what it is, rather than what it resembles, we shall find qualities, uses and advantages worthy of exhaustive research. (Rice 307)

Having begun its existence as a substitute material, cast stone suffered the consequences of being labeled second best.

With the maturation and dissemination of the Portland cement industry in the United States during the period from 1900-1930, cast stone became more durable as well as more popular as an architectural material. In these first three decades of the twentieth century, the cast stone industry experienced the most innovations, technological advances, and attention making this period in the history of cast stone the most significant. The use of white Portland cement allowed the cast stone mixture to be more easily and effectively colored to match the stone it sought to imitate. In referring to cast stone made with Portland cement, one author wrote in 1906,

> This form of artificial stone is now extensively used as a substitute for natural stone, for window heads, string courses, sills, columns, copings, keystones, and many other architectural, constructive, and decorative features. (Hodgson 431)

In the United States, cast stone or concrete was heralded in a social context because the material seemed to reflect the precepts for the growth of the nation.

> The artificial commingling of all races known in America, like the artificial mixture known as concrete are both made up of ingredients moved from their original beds. In the one case, we have aggregations of men; in the other, aggregates of materials. (Cahill 43)

Before 1900, there were no standards for the manufacture and use of Portland cement in the United States and consequently, cast stone was considered less reliable than natural stone in terms of strength. In 1904, standards for the manufacture and use of Portland cement were established by the American Society for the Testing of Materials (ASTM) and the Engineering Standards Committee (now the British Standards Institution). (Lea 8) With the increased production and standardization of the Portland cement industry, cast stone was given more credence in terms of its durability and strength as a building material.

> Geology teaches us that our best building stones, outside of the original rocks, such as granite or gneiss are made by the depositing at the bottom of large bodies of water of the fine particles of minerals that are held in suspension. These particles being deposited in strata or beds, which are afterwards cemented together, and sometimes altered by the chemical action produced by the heat evolved in the enormous pressure of the Earth's crust. The processes and methods employed in making cast stone are practically the same, except that the chemical action required to cement the particles is produced in a few hours by the use of our modern highly developed Portland cement while nature has required centuries to produce conditions by which she has brought about practically the same chemical action. (Watson 838)

When cast stone became better accepted as a building material worthy in its own right, an aesthetic more exclusively based on cast stone or concrete emerged. After 1930, a trend towards the use of more utilitarian concrete rather than decorative or imitative cast stone began. Furthermore, the Depression could not support the care and expense for the

manufacture of fine cast work so cast stone production began to diminish after this time. (Stauffer 27)

At the time the Palacio Errazuriz was constructed, the building practices in Argentina were heavily influenced by French design and technology. Given that there was little access to local building stone in Buenos Aires at that time, it is not surprising that there are many examples of buildings with imitative ornamental cast stone. It is reasonable to presume that the French practice and innovation in the early cast stone industry had an influence on early twentieth century buildings in Buenos Aires, just as French architectural design had a profound impact. The use of imitative cast stone in Buenos Aires is visible in many examples, such as the Atucha residence (c. 1914) and the Palacio Bosch (c. 1910) — both designed by René Sergent in the manner of the Parisian *hotels de ville*. (see Illustrations 15 and 16)

8.0. MANUFACTURE OF CAST STONE

Cast stone mixtures were not standardized in the United States until 1917. (Stauffer 41) Although little information is known about the methods of manufacture of cast stone in Argentina, there are sources on the manufacture of the material in North America and Europe. In fact, it was probably French practice and tradition that dictated how the material was used at the Palacio Errazuriz. The following methods and practices may be quite similar to what was used in the construction of the Palacio.

8.1. Aggregates

The characteristics and quality of a cast stone product is influenced by the aggregate used in the mixture. Ideally the aggregate should be clean, hard, and dense. Crushed granite, like the natural building stone, was considered to be the best aggregate. Dolomite and marble exhibited good resistance to erosion due to their density and low porosity and their specular reflection gave brilliance to the mixture. Orthoclase, quartz, and pure minerals also made good aggregates, but plagioclase and the black silicate minerals proved to be less durable. (Stauffer 43) Limestone was the aggregate used most often for cast stone and it proved to resist weathering well, but would weaken if repeatedly exposed to moisture. (Stauffer 44) The use of aggregates really depended upon the type of stone that was being imitated taking into consideration the texture, color, size, and of course, availability.

8.2. Mixing

Early methods of mixing were by hand where the mixture was tamped into molds in a relatively dry consistency. The principal difficulty in the manufacture of early cast

stone was the requirement of sufficient pressure to properly compact the mixture. (Watson 839) The result was a weak product in which the binder did not bond with all the aggregate making the material too porous, poor in cohesive strength, and more susceptible to moisture penetration. The "dry" mixing process yielded a porous product more likely to stain. Improvement in the manufacturing of cast stone came with the so-called "wet process" which utilized much more water in the mixture allowing the greater compression and cohesiveness among particles. This process became popular in the United States around 1910 although it was described in a paper presented to the New York Concrete Association in 1906. (Watson 839) The wet process was further improved with the use of mixing machines that ensured a homogeneous mixture. The product was often cast in two pours — a fine facing that contained the correct mixture which yielded the intended appearance and a coarser backing material whose materials were more heterogeneous. Finely ground and well graded aggregate was used for facing materials because it was easier to imitate the fine grains in natural stone. The bulk of the material underneath the face was not a particularly special mixture, but tended to be a bit coarser with greater aggregate-to-paste ratio.

Common proportions for cast stone facing material were 3 parts aggregate to 1 part Portland cement (by volume), whereas the more common backing material was made with 5 parts aggregate to 1 part cement. White Portland cement was advantageous over ordinary gray Portland or other natural cements in order to achieve the desired color of the stone to be imitated.

8.3. Surface Treatments And Finishes

Exposing the facing material in a cast stone product was a common practice used to better reveal the grains of the aggregate and to erase mold lines. This was

accomplished by either spraying the uncured product with water, wire/steel brushing, or by treating with acids, such as muriatic acid.

> The exposed film of cement which coats the aggregate is removed from the surface by brushing while still green with a steel brush.... After brushing, the work should be washed with a solution consisting of 1 part of commercial muriatic acid and 3 parts of water. (Whipple 242)

This procedure would have been done before installation at the workshop while the cement was still leathery and not yet fully cured.

8.4. Additives

A variety of pigments were traditionally used in cast stone mixes, but it was soon discovered that vegetable pigments were detrimental to the stability of the product. As early as 1900, manufacturers realized that mineral oxides were the only pigments alkali and light stable enough for cast stone. (Stauffer 49)

> Mineral colors of the highest degree of purity are the only kind to use in coloring cement. The permanence of shade of color obtained depends upon the elimination by the manufacturer from the color of anything that the cement itself will destroy, for otherwise, the ultimate result would be cement discolored.... (Whipple 235)

8.5. Molds

In general, wooden molds were considered suitable for most casting, however, for castings with a great amount of detail or ornament, plaster molds were used. Piece molding was a common method for making a cast object, such as a bracket or modillion. (Millar 269) (see Appendix 13.2) A model of the desired object was divided into sections and plaster casts were made of different parts of the object. In the case of a bracket, one side could be sectioned off with clay dividers in order to make a plaster cast of one side. The various sections of this piece mold were recombined to form the shape of the desired object, and repeated castings were then made.

The facing material — usually having a finely-graded aggregate in low proportion to the binder — was poured into the mold first with the coarser-graded backing material behind it. A finely ground cement made sharper casts and set more quickly.

As was done with natural stone, it was common to coat cast stone with a slurry consisting of lime, stone dust, and sometimes a little plaster to protect it before it was placed on the building. (Childe, 1964, 124) This protective coating was then carefully removed after the cast stone had been installed.

9.0. CHARACTERIZATION AND ANALYSIS OF CAST STONE AND STUCCO

Initial characterization and classification of the exterior masonry materials were performed light microscopy. After the basic types of cast stone, stucco, and natural stone were classified, more detailed examination and analysis were necessary.

9.1. Gravimetric Analysis

Representative samples were chosen for gravimetric analysis in order to further type the materials that were identified through visual examination and to isolate various components such as the fines and aggregate for further study. This was done by first grinding the sample by hand using a mortar and pestle separating the matrix of aggregate and binder in order to react the acid-soluble fraction with hydrochloric acid (3M). After acid digestion, the non-soluble fraction was separated by levigation and the fines filtered. The remaining coarser fraction — mostly aggregate — was then dried and sieved.

Comparative gravimetric analysis (as developed by Hanna Jedrzejewska), as its name suggests, is a method of comparing the characteristics of different mortar mixtures. It should be noted that this method provides information that is relative to other data and not a definitive means of identifying the material being analyzed. This method of analysis works only if the aggregates do not contain carbonates. If there were carbonate aggregates in the sample, they would be part of the acid-soluble fraction and therefore not be considered when determining the ratio of aggregate. Gravimetric analysis provides a simple method for determining the approximate ratio of binder to aggregate. The method also gives a good indication of the physical attributes of the aggregate used in the mixtures. Information about the color and the methods of manufacture also helps to identify the original appearance of the material.

Samples ER 1, ER 2, ER 28, and ER 34 were chosen because they represented two visually different cast stone mixtures and two different stuccos. The gravimetric data proved inconclusive in terms of providing information about the approximate ratio of binder to aggregate because of the difficulty in dissolving or reacting all of the binder. It proved very difficult to completely grind the hard cement matrix so all of the binder may not have reacted with the acid.

The analysis, however, provided an excellent means for aggregate typing and granulometry. Also of great value from this analysis was the identification of the color of the fines. The original color of the cast stone and stucco became more evident after viewing and analyzing the non-soluble fines.

9.2. Optical Light Microscopy

Samples were initially examined to record general micromorphology and physical characteristics such as layer structure; dimension; paste color; texture; grain shape, size, color, and distribution; and other features such as additives. Gross samples were examined in normal reflected light using a variable magnification stereo microscope [Nikon SMZU (10x-75x)] and were grouped into categories according to their physical characteristics and their type as architectural elements.

Representative samples were mounted in a commercial polyester/methacrylate resin (Bioplast™) polymerized with a methyl ethyl ketone peroxide catalyst and cured under a tungsten light. The samples were sectioned on a Buehler Isomet™ micro-saw for microscopic examination. The sectioned samples were polished using fine abrasive paper (600 grade) and an alumina powder (Buehler Micropolish II, 0.05 micron) on a felt cloth. Embedded and sectioned samples were examined using reflected quartz-halogen light stereo microscopy and polarized light microscopy (Nikon Optiphot 2).

Many samples were prepared for microscopic examination in the form of mounted cross-sections. Three samples are illustrated as representative examples of the method used to characterize these samples and to help clarify discussion of samples in the paper. The following samples are: ER 1, a cast stone rosette; ER 2, a cast stone cornice console; and ER 28, stucco that was scored to resemble masonry. (see Appendix 13.3 for sample analysis)

9.2.1. Thin-Sections

Representative samples based on the types characterized in the initial examination were sent to a petrographic laboratory for thin-section preparation. Examination of thin-sections using polarized light microscopy provided confirmatory evidence of the initial observations and hypotheses regarding the types of materials and their characterization. Aggregate size and the approximate paste to aggregate ratio was verified by comparing the thin-sections to cross-section and gravimetric analyses. There was a correlation between the cross-sections, thin-sections, and gravimetric analyses. This information was important in understanding the technology used in construction of the building and in understanding observed deterioration.

Information about the micromorphology, including porosity, of the materials was obtained from thin-section examination as well as questions about durability and weathering of the materials. Mineralogical analysis of the aggregate was not performed.

The samples do not appear to have weathered poorly, but in most samples, it is evident that surfaces have slightly eroded as revealed by empty spaces where aggregate has been lost. This superficial erosion is most likely due to the mechanical cleaning by sandblasting documented in 1978.

9.3. Scanning Electron Microscopy/Energy Dispersive X-Ray Analysis

Representative samples were chosen for further compositional analysis provided by Scanning Electron Microscopy (SEM) and Differential Thermal Analysis (DTA). An understanding of the microstructure and the elemental composition of the samples can provide important information about the methods and materials of manufacture, intrinsic durability, and weathering properties of the materials.

Three representative samples were chosen for Scanning Electron Microscopy (SEM) and Differential Thermal Analysis (DTA). The samples chosen were: ER 1, a cast stone sample from a rosette under the cornice on the east facade; ER 2, a cast stone sample from a cornice console also on the east facade; and ER 28, a stucco sample from an area scored to look like masonry on the north facade.

In order to remain consistent and provide comparative information for the results of the thermal analyses, samples ER 1, ER 2, and ER 28 were chosen for SEM. These samples were chosen because they each represent a unique feature in terms of the materials used on the Palacio. ER 1 is a cast stone sample with a uniform internal color. ER 2 is a cast stone sample that exhibits chromatic variability or swirled appearance in cross-section. ER 28 is representative of the two-coat stucco scored to simulate masonry on the building. (Only the finish coat of the stucco was analyzed with DTA because of the interest in learning about the original surface appearance of the building).

Scanning Electron Microscopy with Energy Dispersive X-Ray Analysis represents an extremely useful method for gaining qualitative information about the samples. The X-rays are generated by the interaction between the electron beam and the sample. These X-rays are collected and sorted by computer according to their elemental identity, thus providing information about the elemental composition of the sample. Analysis of the spectra in the sample reveal information about the concentrations of

specific elements and line scan analysis can display the relative concentration of elements along a certain line.

In Scanning Electron Microscopy (SEM), a sample is placed in an evacuated chamber where a fine beam of electrons is focused on the sample. The signals that result from the interaction between the electron beam and the sample can be utilized in different ways. The electron beam which interacts with the sample may be used to provide morphological information about the sample, not unlike that in reflected light microscopy, but at a magnification up to 100,000x with a greater depth of field.

Samples prepared for Scanning Electron Microscopy (SEM) were already embedded in a polyester/methacrylate resin (Bioplast™), sectioned on a microsaw, and coated with carbon. Samples were examined using a JEOL JSM 6400 Scanning Electron Microscope at 20x (at 25kv).

Elemental composition was easily visualized by mapping various elements with the Energy Dispersive X-Ray Analyzer (EDX) coupled with the SEM. Several elements were identified within the paste such as calcium and silicon. (see Illustrations 17 and 18) Iron was scanned in order to determine the presence of iron-based pigments and whether or not the observed internal discoloration was related to iron staining. Magnesium and aluminum were scanned because they are definite components of cement and may provide some information regarding the cast stone mixtures. Chlorine was scanned as a contaminant salt that would be expected in a marine environment such as Buenos Aires. Sulfur was scanned because it is indicative of sulfate crusts associated with atmospheric pollution, or a possible gypsum finish layer, or the presence of gypsum as an additive in the mixture. The strong presence of sulfur identified within the white band in sample ER 2 is likely to be gypsum used as an additive. (see Illustration 20)

9.4. Differential Thermal Analysis/Mass Spectrometry

Differential Thermal Analysis (DTA) is an analytical technique based on the principal that all elements undergo characteristic effects upon heating and leave a "fingerprint" that can help identify them. DTA coupled with Mass Spectrometry (MS) provided qualitative and quantitative information regarding compounds present in the sample. In mass spectrometry, the ions evolved from a vaporized sample travel through a column or tube until they settle and separate according to their different weights. In this case, Mass Spectrometry was used to identify elemental composition and expected compounds were present.

Thermal Analysis was pioneered, in part, by James Ballantyne Hannay (1855-1931) in Glasgow, Scotland. Hannay worked on the weight loss of samples read at regular intervals while the sample was heated at a constant temperature. This method was referred to by Hannay as the "Time Method" and is the predecessor of today's Thermal Analysis. Hannay first applied the "Time Method" to the study of gypsum ($CaSO_4 \cdot 2H_2O$) identifying the existence of bassanite ($CaSO_4 \cdot 1/2H_20$) and anhydrite ($CaSO_4$).[2]

In preparation for DTA/MS, two cast stone samples (ER 1 and ER 2) and one stucco sample (ER 28) were first crushed using an agate mortar and pestle. The crushed samples were then sieved and the fines that collected in the pan (passing screen no. 200) were analyzed. (The coarser aggregates were omitted from the analysis).

Approximately 10mg of each sample were heated in an Argon gas atmosphere for approximately 48 minutes at a rate of 20° C/min. to the temperature of 1000° C in a Seiko 320 TG/DTA Thermal Analyzer. The use of a Thermolab Mass Spectrometer provided information about the elements and compounds present in the sample.

[2] C. J. Keattch and D. Dollimore, "Studies in the History and Development of Thermogravimetry, *Journal of Thermal Analysis 37* (1991): 2103-2107.

In order to help evaluate the DTA of samples from the Palacio, standards of Portland cement mixed with lime; gypsum mixed with lime; and an Argentine hydraulic lime (Loma Negra brand) were analyzed for comparison.

All the DTA graphs showed a steep peak at around 750° C characteristic of calcium carbonate (lime). The analysis also proved conclusive for the presence of gypsum in the mixture of sample ER 2. A peak at around 440° C in ER 2 matched a characteristic peak in the DTA of the standard hydraulic lime sample from Argentina. Peaks at 440° C in sample ER 2 and at 405° C in the standard hydraulic lime sample may suggest the presence of clays in the limestone from which hydraulic lime is made. The DTA of sample ER 1 closely resembles the standard for lime and Portland cement which indicates a slightly different cast stone mixture than sample ER 2. (see Appendices 13.4.1 and 13.4.2) The DTA from sample ER 28 (stucco) resembles that of the standard for calcium carbonate implying that the stucco is mostly lime based. (see Appendix 13.4.3)

9.4.1. DTA Calculations (% Calcium Carbonate)

Differential Thermal Analysis is interpreted by reading graphs which measure the loss of weight at intervals over the time during which the sample is heated. The analysis produces a graph that measures both time and temperature on the horizontal axis and % weight loss along the vertical axis. There are three curves in the graphs generated by this analysis: 1) Thermal Gravimetry (TG) or % weight loss (blue); 2) Differential Thermal Gravimetry (DTG) or % weight loss/time (red); and 3) Differential Thermal Analysis (DTA) which reflects the DTG curve (green). The differential in thermal analysis is expressed as % weight loss/time.

An easy and useful method of interpreting the graphs generated by DTA is to calculate the approximate percentage of calcium carbonate in the sample. A combination

of lines are drawn over the graph to extrapolate the % loss of CO_2. First, two lines are placed along the predominant angles of the TG curve (blue). A third line is drawn horizontally from the intersection of lines 1 and 2 to the axis that measures % weight loss. The value taken at this point approximates the % weight loss at the moment when most of the H_2O in the sample has been driven off. The difference between the point of water loss and the end of the analysis approximates the % CO_2 loss. With the % CO_2 loss, one can determine the approximate % $CaCO_3$ in the sample.

FORMULA:

$$\text{Starting weight } CaCO_3 \text{ in sample (unknown)} = \frac{\text{Total final weight} \times \text{Molecular weight } CaCO_3}{\text{Molecular weight } CO_2}$$

KNOWN WEIGHTS:

Molecular Weight of Ca CO_3 :

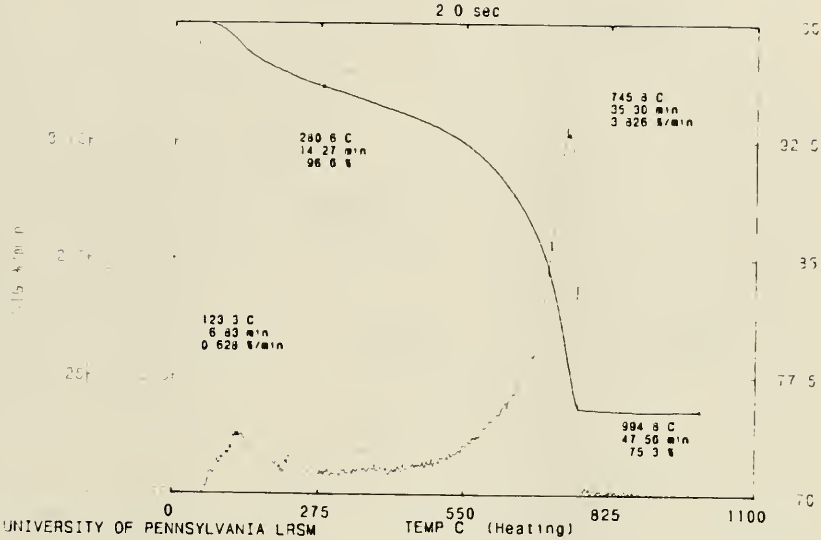
Ca = 40 x 1 = 40
C = 12 x 1 = 12
O = 16 x 3 = 48
100 total

Molecular Weight of CO_2 :

C = 12 x 1 = 12
O = 16 x 2 = 32
44 total

Sample ER 1

Starting weight of sample ER 1 = 10 mg



(8% H_2O)

(17% CO_2)

17% CO_2 ÷ 10 mg starting weight of sample ER 1 = 1.7 mg CO_2

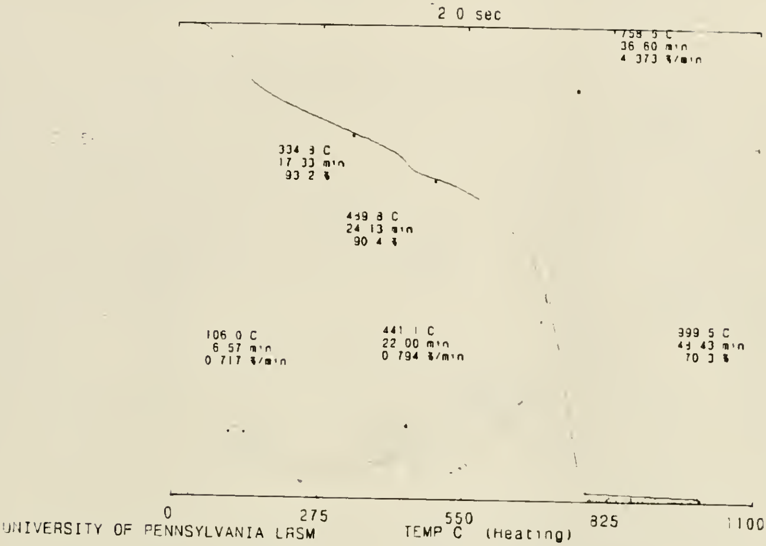
$$\frac{1.7 \text{ mg } CO_2 \times 100 \text{ g } CaCO_3}{44\text{g } CO_2} = 3.86 \text{ mg}$$

≈ 4 mg $CaCO_3$ in sample ER 1

approximately 40% of sample ER 1 is $CaCO_3$

Sample ER 2

Starting weight of sample ER 2 = 9.8 mg



(12% H_2O)

(18% CO_2)

18% CO_2 ÷ 9.8 mg starting weight of sample ER 2 = 1.8 mg CO_2

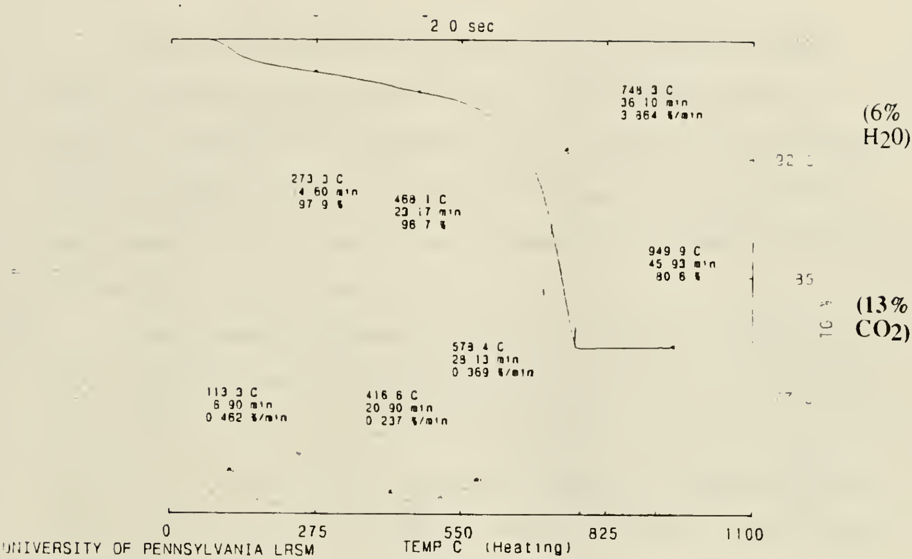
$$\frac{1.8 \text{ mg } CO_2 \times 100 \text{ g } CaCO_3}{44 \text{g } CO_2} = 4.09 \text{ mg}$$

≈ 4.0 mg $CaCO_3$ in sample ER 2

approximately 40% of sample ER 2 is $CaCO_3$

Sample ER 28

Starting weight of sample ER 28 = 9.5 mg



13% CO_2 ÷ 9.5 mg starting weight of sample ER 28 = 1.3 mg CO_2

$$\frac{1.3 \text{ mg } CO_2 \times 100 \text{ g } CaCO_3}{44\text{g } CO_2} = 2.9 \text{ mg}$$

≈ 3 mg $CaCO_3$ in sample ER 28

approximately 30% of sample ER 28 is $CaCO_3$

10.0. CONCLUSIONS

10.1. Masonry Materials Used at the Palacio Errazuriz

Differential Thermal Analysis suggests the use of two different cast stone mixtures used for the exterior ornamental masonry. One mixture appear to be a combination of Portland cement and common lime (i.e., sample ER 1) as it correlates to the DTA standard for Portland cement and lime (see Appendix 13.4.1). The other cast stone mixture (i.e., ER 2) contains common lime and another ingredient — most likely hydraulic lime or natural cement.

There is convincing evidence for the presence of hydraulic lime in sample ER 2. DTA of sample ER 2 shows a peak at 440° C that correlates to the peak in the standard for hydraulic lime that occurred at 405° C. The mention of "Tierra Romana" in the specifications for construction from Lanus y Hary is curious and its meaning unclear. The reference to "Tierra Romana" is for an "imitation stone" mixture that calls for 1 part (by volume) "Tierra Romana," 1 part cement, and 3 parts sand. (see Appendix 13.5) As cement is already prescribed for the mixture, it is likely that this "Tierra Romana" is an hydraulic lime, natural cement, or pozzolana. Both natural and artificial cements were certainly available in Argentina, if not manufactured directly in Buenos Aires at the time the Palacio was built. (see Appendix 13.6)

While cast stone on the Palacio Errazuriz undoubtedly was employed as an economic alternative to natural stone, it has been suggested that the original intent of the architect and builders may have been the use of a lesser amount of cast stone and a greater amount of imported natural stone.[3] It is known that World War I hindered the safe transport of materials from France to Buenos Aires, as documented evidence states that the first iron railing for the property was sunk at sea during transport from France.

[3] This theory was suggested by project architect Fabio Grementieri.

Another fence was successfully sent to Buenos Aires, but this may have discouraged further importation of materials for the building. If more natural stone had been intended and importation was impossible, the most efficient alternative would have been the use of cast stone, a practice already highly developed in France at the time. Since French design influenced the building, it is likely that French technology and the tradition of decorative cast stone was also employed. This is not to suggest that the methods of manufacture of cast stone used at the Palacio were a particular French technique or patent. It is very difficult to speculate the exact method of manufacture, but analyses have revealed that the cast stone mixtures used on the building were typical of those in Europe and in the United States.

Surviving receipts indicate that imported French stone was delivered to Buenos Aires for construction of the Palacio Errazuriz in 1912. (see Appendix 13.7) It is likely that the molds for the cast stone elements also came from Paris as suggested by the same receipt that includes "modèles (pris à Paris)" which are believed to be the molds for casting the artificial stone. It is probable that the cast stone elements for the Palacio were made from these plaster "models" in Buenos Aires.

10.2. Original Appearance

The original surface appearance of the Palacio is difficult to understand because the building's finishes have altered through natural weathering and human intervention — namely painting and sandblasting. Examination and analysis of the cast stone, stucco and natural stone, in coordination with site inspection, has led to the conclusion that the Palacio Errazuriz was originally intended to have an overall monochrome appearance. The careful examination of the cast stone reveals that it has a subtle, varied surface appearance that was probably due to intentional or unintentional inconsistencies in the manufacturing process. The cast stone may not have been evenly mixed or the setting

and drying process may have left a variegated surface appearance. On the other hand, the production of cast stone was a technologically sophisticated practice at the time and it is plausible that this subtle variegated surface appearance was intentionally designed into the manufacturing process. The builders of the Palacio may have taken their cue for the cast stone from the fact that natural stone possesses random and subtle variations in color. (see Illustration 13)

The original appearance of the building has changed with time and it appears that the cast stone elements have generally darkened. This is most likely due to soiling from atmospheric pollution and organic staining. Cleaning tests on samples reveal a surface appearance that more closely resembles the natural limestone on the building. (see Illustration 12)

Cross-section examination revealed that sample ER 1 was cast with one pour, whereas other cast stone samples, such as ER 2, probably exhibit a two or three pour system. The existence of single pour castings can be explained by the thickness or depth of the casting and the type of element being cast. Those cast stone elements that are small or relatively thin or shallow, such as ER 1 (a rosette) and ER 9a (a foliated window architrave molding), were cast with one pour. Larger cast stone elements that were made using two or more pours are thicker and would take longer to set.

The presence of gypsum would help explain the chromatic variation seen in cross-section. There is evidence of sulfur deep within sample ER 2 as determined by SEM/EDX analysis (see Illustrations 19 and 20) which would suggest the presence of calcium sulfate (gypsum). It is possible that gypsum was used as an additive to help quicken the set of the castings because of its fast setting time. By this theory, it would stand to reason that the finer, thinner elements, such as the rosettes would nor necessarily be cast with an additive to quicken the setting time, but a larger, thicker element such as the console would receive a quantity of gypsum in the mix.

It is in the thicker, larger cast stone elements such as consoles, swags, and garlands that there may be the possibility of gypsum added to quicken the setting time. The chromatic variation seen both on the surface and in Cross-section is also explained by the two-pour system in which one wet mix is applied on another forcing the different mixtures to intermingle. On the other hand, a thinner sample such as ER 1 would appear relatively uniform in color in Cross-section as there was only one pour.

10.3. Changes in Appearance

Fragmentary evidence of a thin white finish on the cast stone elements was observed on site suggesting the use of an original or subsequent surface finish. Cleaning tests on a rosette fragment revealed a soiled surface between this finish and the original cast stone surface thus suggesting its later application. When the new wing of the Museum was added in the early 1940s it is likely that a general maintenance of the site was undertaken. The cast stone elements on the original structure may have been painted white at that time because, as the cleaning tests revealed, they had darkened slightly over time.

Microchemical analyses of the white surface finish proved to be positive for carbonates, but negative for sulfates and calcium. Although the building may have been finished with a carbonate wash at some point in its history, there was no evidence of a calcium-rich crust on the samples analyzed to suggest a lime wash.

The presence of a sulfur rich crust on samples ER 1 and ER 2 probably indicates the effects of pollution. (see Illustrations 20, 21, 22, and 23) Sulfur in the atmosphere from industrial production combines with moisture in the atmosphere to react with carbonate-rich masonry and forms sulfate crusts. These sulfur-rich surface layers may also be evidence of a gypsum (calcium sulfate) finish or the presence of bacterial action, but the location from which samples ER 1 and ER 2 were taken suggest another theory.

These samples are from cast stone elements placed under the shelter of the cornice that, as a consequence, do not receive the effects of rain water washing that would remove such sulfate crusts. Where the building is not sheltered, such as on the stucco facade, sulfate crusts do not occur. (see Illustrations 24 and 25)

Free sulfur or the combination of sulfur in red and brown pigments was cited as causing cast stone to soil and turn darker. (Jackson 208) It is possible that the sulfur in the cast stone — due either to gypsum being added to the mix, the presence of certain pigments, or sulfur crusts related to atmospheric pollution — may have darkened the elements slightly.

The trace evidence of chlorine on the surface of sample ER 28 may indicate the presence of soluble salts that are easily attributable to the maritime location of Buenos Aires, but the amount of chlorine present was negligible.

10.4. Recommendations for Further Analysis

It may be possible to further determine the exact composition of the stucco and cast stone at the Palacio Errazuriz through the use of X-Ray Diffraction (XRD), a method used for the identification of crystalline materials. In XRD, a sample is irradiated with a beam of X-rays that is diffracted or reflected by the crystals within the atomic structure of the sample. The way in which these X-rays are diffracted is characteristic of certain crystalline materials. While DTA/MS provides quantitative information about the separate compounds present in a sample by measuring the different gases evolving from the vaporized sample, XRD analysis can determine the actual formula of the various compounds and how they are relate to each other. Different crystalline materials have distinct patterns that are recorded in XRD and by comparison with known references of pure crystalline materials, further information about the binders used for the cast stone mixtures at the Palacio can be obtained.

11.0. GENERAL RECOMMENDATIONS FOR MASONRY CONSERVATION TREATMENTS

The aim of providing general recommendations for the conservation of the exterior masonry materials at the Palacio Errazuriz is: 1) to stabilize and retain damaged original masonry; 2) to visually reintegrate the facades in accordance with the original design intentions; and 3) to provide better maintainability of the exterior masonry.

11.1. Cast Stone

Recommendations for the conservation of the cast stone elements on the Palacio Errazuriz should begin with the removal of all poorly executed or defective repairs. All surface mounted metallic fasteners, such as nails, should also be removed. Cracked and detached original material should be faced with wet strength paper or cotton gauze and a reversible adhesive such as polyvinyl alcohol (PVOH) or Acryloid B-72. All loose intact ornamental pieces should be removed, labeled, and stored for future reinstallation. All cracked, spalled, and detached elements should be stabilized and missing portions of cast elements repaired or replaced where necessary.

In preparation for treating cracks with no exposed reinforcing bar, the cracks should be cleaned out with compressed air and water using low pressure. The cracks should then be injected with a cementitious grout such as Jahn M30 for cracks 0.2 - 5.0 mm, Jahn M40 for cracks 5.0 mm to 10.0 mm, or Jahn M50 for cracks or voids 10.0 mm or larger. The grout should be injected up to approximately 1/2 inch from the surface using hand held syringes with various sized canulae depending on crack width and depth.

For cracks with exposed reinforcing bars, the same preparation outlined above should be carried out. After stabilizing the surrounding cracked cast stone with facings as described above, the exposed reinforcing bar should be mechanically cleaned with an air-

pressurized micro abrasive. All flaking and corroding metal should be mechanically removed, the surfaces degreased, and an epoxy primer, such as Sikadur 22, should then be applied to the remaining metal. For elements requiring additional or replacement reinforcement due to corrosion, new stainless steel and/or threaded nylon rods of appropriate diameter should be installed in combination with an epoxy adhesive such as Sikadur 30. After being treated, all cracks and losses should be filled and finished to match the existing cast stone with a composite mortar repair similar to the original in color, texture, and weatherability.

Fills should be undercut behind the existing masonry where possible in order to provide a mechanical key for the fill material. The fills should be installed in single layers no greater than 1/2 inch and scored to provide a mechanical key between layers. Non-corroding reinforcement pins may be necessary depending on the size and shape of the loss.

11.2. Stucco

Conservation of stucco on the Palacio Errazuriz should begin with the removal of all poorly executed or defective repairs. Cracks in the stucco should be injected with a cementitious grout such as Jahn M40 for cracks 5.0 mm to 10.0 mm or Jahn M50 for cracks or voids 10.0 mm or larger. The grout should be injected up to approximately 1/2 inch from the surface using hand held syringes with various canulas depending on crack width and depth. Large areas of loss and cracks should be filled with a composite mortar repair that matches the color, texture, and coarseness of the existing stucco. Fills should be made as described above in the treatment of cast stone fills.

11. 3. Facade Cleaning

The facades should be cleaned with a continuous or intermittent water spray using low volume and low pressure. The facades should be washed from top to bottom. After a general soaking of the facades, particularly soiled areas can be returned to for further washing with a low pressure water lance (200-600 psi).

Discrete tests for any chemical cleaning being considered must be done on the stucco and cast stone before any full scale treatment. Cleaning tests should include prolonged water washing, detergent cleaning, and acid cleaning with a commercial restoration cleaner such as ProSoCo Restoration Cleaner.

11.4. Final Repairs And Replacement Of Cast Stone Ornament

After cleaning, final repairs and replacements to the cast stone and stucco should be made to match the existing materials in color and texture. **Repair** of cast stone ornament should be made when less than 50% of the element remains. When greater than 50% of the element is lost or damaged, the element should be **replaced** with a new casting. Small patching repairs can be built up by hand in place and larger missing pieces can be substituted with dutchman cut from new casts. New casts should be attached with non-corrosive stainless steel or threaded nylon pins. Molds should be taken of each type of ornament using an example in good condition. A high quality molding material with good longevity should be used. The most complete piece molds possible should be made. Casts of the following elements are necessary for new cast replacements:

Cornice:

- baluster
- cornice
- console
- rosette
- egg and dart molding

Architrave:
- acanthus molding (a)
- acanthus molding (b)
- water leaf molding

Second Story:
- bead molding
- rectangular window over garland
- roundel window over garland
- window water leaf molding
- console and swag spandrel

First Story:
- acanthus leaf molding
- egg and dart molding
- acanthus molding (a)
- acanthus molding (b)
- water leaf molding

During the March 1995 site visit, an approximate inventory of missing cast stone elements was made and the following list reflects the approximate number of replacement castings that need to be made.

North Facade:
- rosettes..15
- roundel window garland..1/2
- rectangular window garland (proper left half).........2
- console..1

West Facade:
- rosettes..5
- rectangular window garland (proper right half)........3
- rectangular window garland (proper left half).........1
- baluster..1

East Facade:
- rosettes..34
- consoles...2
- roundel window (whole)...1
- roundel window (half)..2
- swag..1

A closer examination of the cast stone moldings such as the water leaf or egg and dart will have to be made in order to determine how much requires replacement.

11.5. Cornice

The coping on the cornice balustrade, the flat cornice, and the raking pediment cornice should have a lead or terne-plate stainless flashing properly detailed into the existing masonry. All upper joints that lie horizontal and are not visible from the ground level should be raked out and filled with a backer rod and elastomeric sealant of appropriate color such as Dow 793.

11.6. Sculpture

The natural stone sculpture needs a detailed conservation study. A general water spray at low volume and low pressure could be used to remove overall soiling and black crusts. Localized chemical cleaning using poultices of ammonium carbonate (AB 57) may be required for removing the tenacious black crusts. The stone must be consolidated after cleaning. Tests on the stone using ethyl silicate should be made to determine its appropriateness. Cracks and detachments can be injection-grouted with an epoxy or Jahn M40 grout and fill mixtures made of hydraulic lime and sand matching the color and texture of the stone used to fill small cracks. Where necessary, non-corrosive pins should be used for structural repair. Finally, the sculpture should be treated with a water repellent.

11.7. East Entrance/Porte-Cochere

The tholos of the east entrance is over-painted up to the cornice. As this facade is in the worst condition, removal of the over paint will likely expose bad repairs as well as deterioration and damage. Test treatments are recommended for steam, abrasive, and

chemical paint stripping and cleaning of the entrance. The conditions visible now are abrasion and impact loss, delamination and scaling, as well as irregular loss of partial paint layers due to water penetration.

11.8. Optional Treatments

Localized weathering and discontinuities in the materials or installation defects have left the facade materials with a non-uniform appearance. An optional treatment could be to visually reintegrate the irregular areas and discolorations of the facade materials with a pigmented lime/hydrated lime wash. The joints of the column drums should also be cleaned out and injected with hydrated lime putty.

Horizontal areas that are prone to pigeon activity should be protected. The pediment and portico can be covered with a mesh designed to keep out pigeons without being noticeable from the ground.

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13.0. APPENDICES

13.1. Original Architectural Drawings for the Palacio Errazuriz from the Office of René Sergent

13.2. Plaster Piece Molding [from William Millar. *Plastering Plain and Decorative.* New York: Truslove & Comba, 1897, p. 269.]

13.3. Cross-Sections

13.4. Differential Thermal Analysis Spectrograms

- 13.4.1. Sample ER 1 Compared with Standard for White Portland Cement and Lime
- 13.4.2. Sample ER 2 Compared with Standard for Hydraulic Lime
- 13.4.3. Sample ER 28 Compared with Standard for Lime and Gypsum

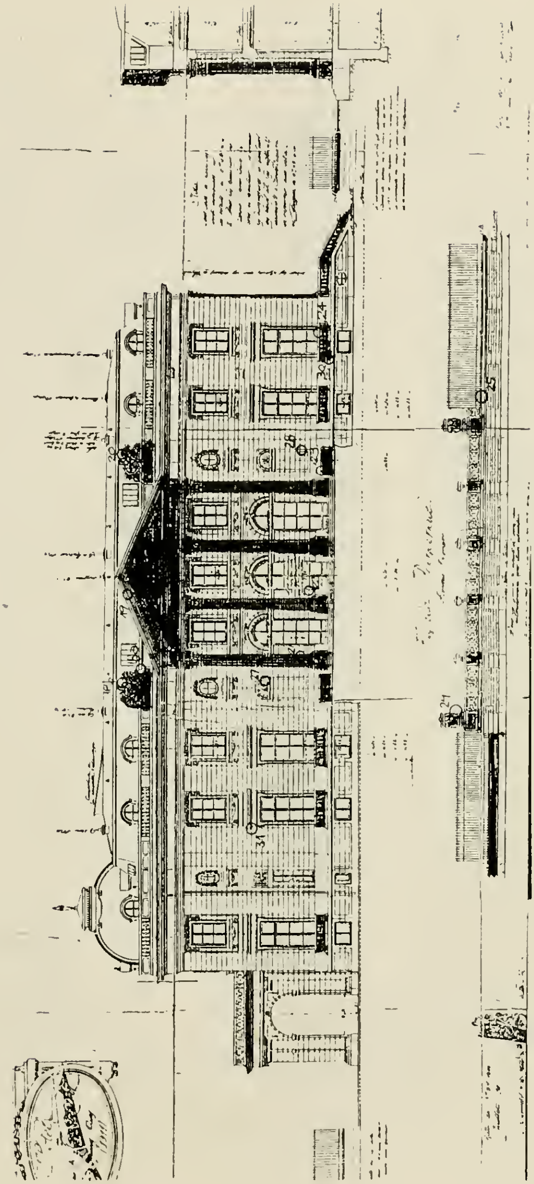
13.5. General Specifications for Construction by the Architectural Contractors, Lanus y Hary

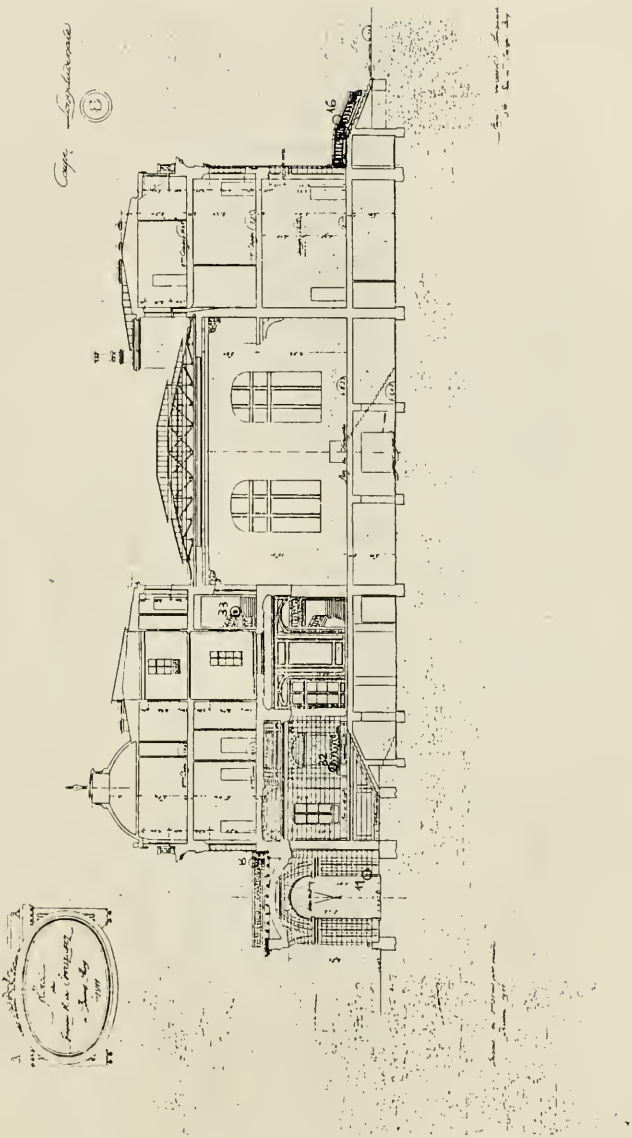
13.6. Cement Advertisement from *Revista De Arquitectura*

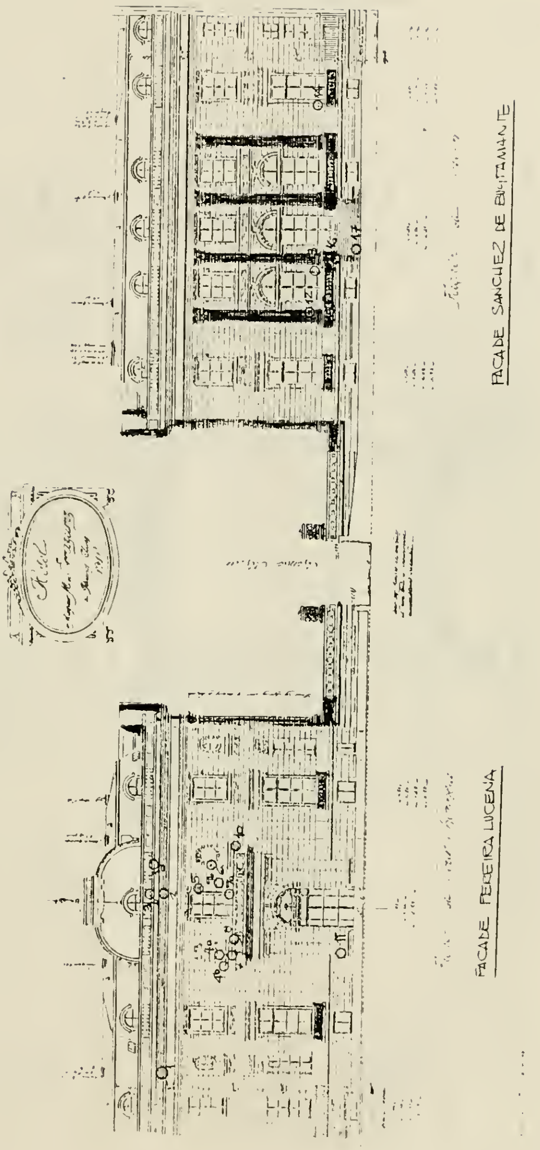
13.7. Receipt for Building Materials for the Palacio Errazuriz

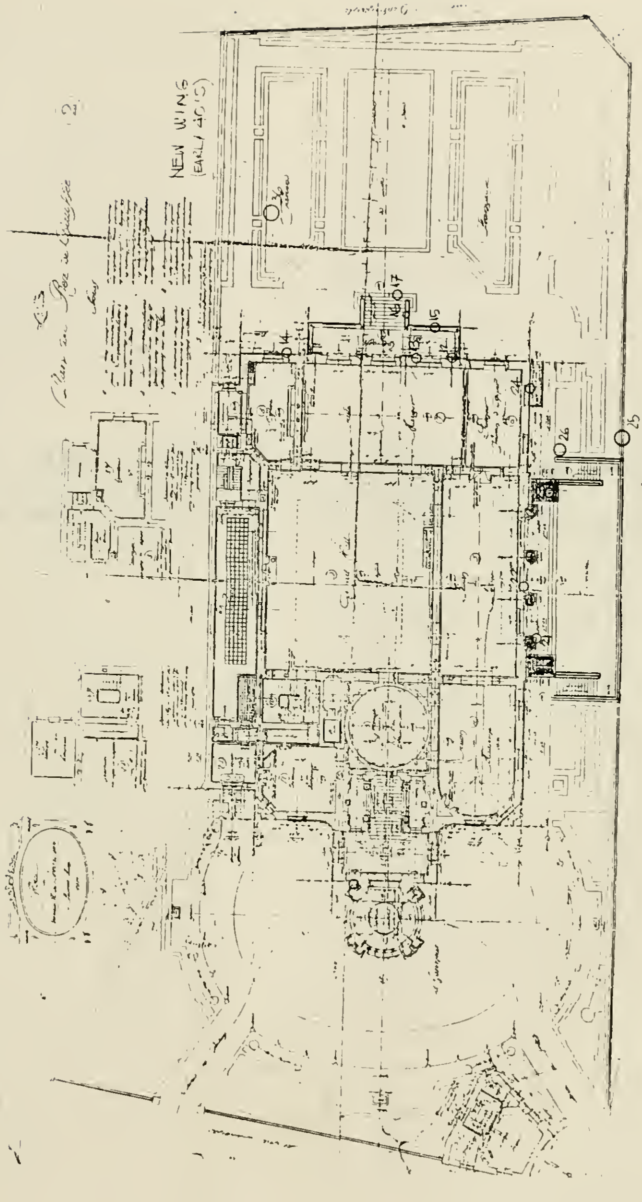
13.8. Sample List

13.1. Original Architectural Drawings for the Palacio Errazuriz from the Office of René Sergent






FACADE SANCHEZ DE BUSTAMANTE
FACADE FERREIRA LUCENA


NEW WING
(EARLY 40'S)
14
15
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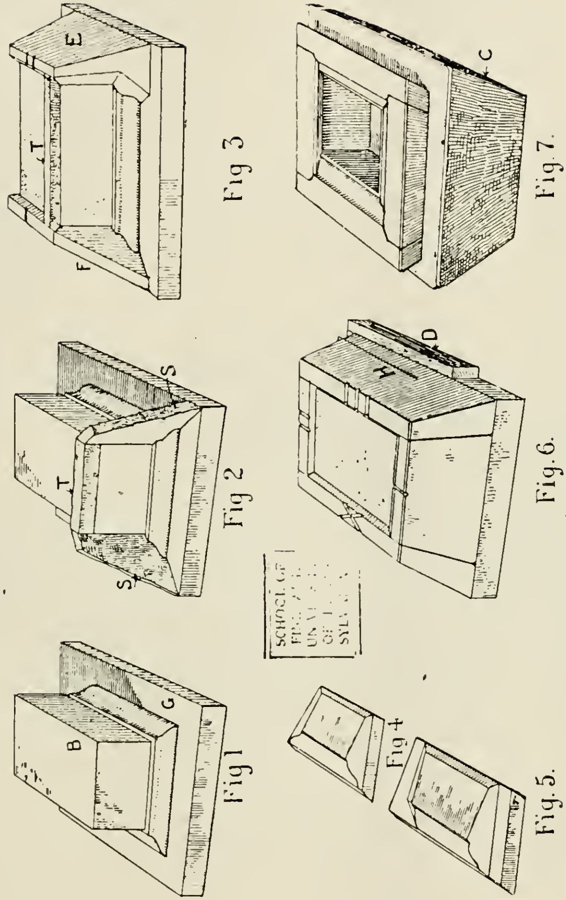
13.2. Plaster Piece Molding from Millar, William. *Plastering Plain and Decorative.* New York: Truslove & Comba, 1897, p. 269.



No. 93.—Plaster Piece Moulding a Modillion.

13.3. Cross-Sections

ARCHITECTURAL CONSERVATION LABORATORY
UNIVERSITY OF PENNSYLVANIA

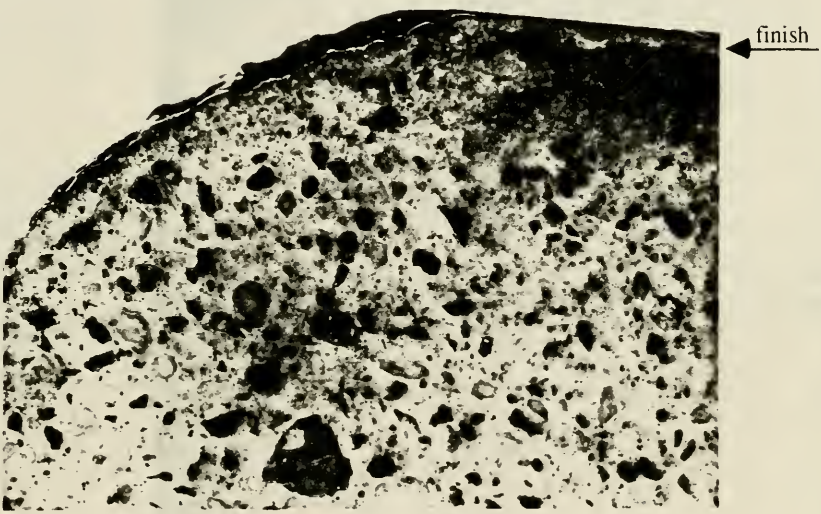
MACROMORPHOLOGY (CROSS-SECTIONS)

Project/Site: Palacio Errazuriz
Location: Buenos Aires, Argentina
Sample taken by: Fabio Grementieri
Examination performed by: James Banta

Date sampled: May 1994
Date examined: October 1994
Sample Number: ER 1
Location: East Facade, proper right (Rosette under cornice)

Material: Cast Stone
Surface Finish: single thin, fragmentary (white, but soiled)
Description: Single-layer casting

The layer is a light yellow-brown paste (2.5YR 7/4-6/4) that consists of heterogeneous and well graded aggregate. The aggregate is predominantly black translucent subangular grains with translucent, yellow, and amber subrounded grains. The paste contains red, orange, and green/blue colored fines; and vacuoles from the casting process.



Camera Ocular: 2.5	Microscope Objective: 1	Total Magnification: 2.5x	
Photomicrograph taken by: James Banta	Film: Ektar	ASA: 100	Filters: daylight

ARCHITECTURAL CONSERVATION LABORATORY
UNIVERSITY OF PENNSYLVANIA

MACROMORPHOLOGY (CROSS-SECTIONS)

Project/Site: Palacio Errazuriz
Location: Buenos Aires, Argentina
Sample taken by: Fabio Grementieri
Examination performed by: James Banta

Date sampled: May 1994
Date examined: October 1994
Sample Number: ER 2
Location: East Facade, center (Cornice console or bracket)

Material: Cast Stone
Surface Finish: none
Description: Single-layer casting with internal chromatic variation

The matrix consists of an off-white paste (10YR 8/1) with a graded heterogeneous, but mostly fine aggregate. The aggregate is predominantly yellow subangular grains with black subrounded grains. The paste contains red, orange, and green/blue colored fines; and spherical vacuoles. There are 4 or 5 subtle bands of chromatic variation within the sample.

chromatic variation

Camera Ocular: 2.5	Microscope Objective: 1	**Total Magnification: 2.5x**
Photomicrograph taken by: James Banta	Film: Ektar ASA: 100	Filters: daylight

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MACROMORPHOLOGY (CROSS-SECTIONS)

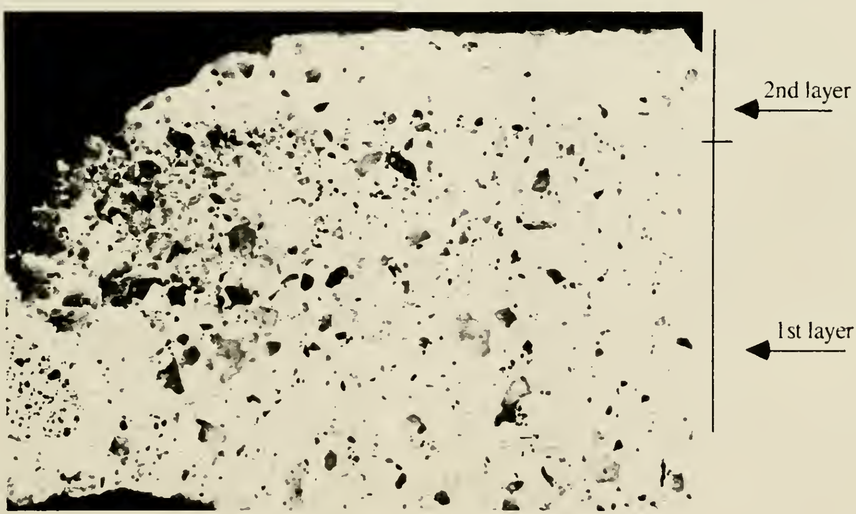
Project/Site: Palacio Errazuriz
Location: Buenos Aires, Argentina
Sample taken by: Fabio Grementieri
Examination performed by: James Banta

Date sampled: May 1994
Date examined: October 1994
Sample Number: ER 28
Location: North Facade. proper left (Stucco scored to resemble masonry)

Material: Stucco
Surface Finish: none
Description: Multi-layer structure

The 1st or base layer has a matrix of a light gray paste (10YR 7/1) with heterogeneous and well graded aggregate. The aggregate is predominantly translucent subangular and subrounded grains with some amber and black subrounded grains. The paste contains red, orange, and green/blue colored fines and a gray composite material. There are vacuoles in the paste that were filled with white polishing powder during sample preparation. This layer is uneven in width.

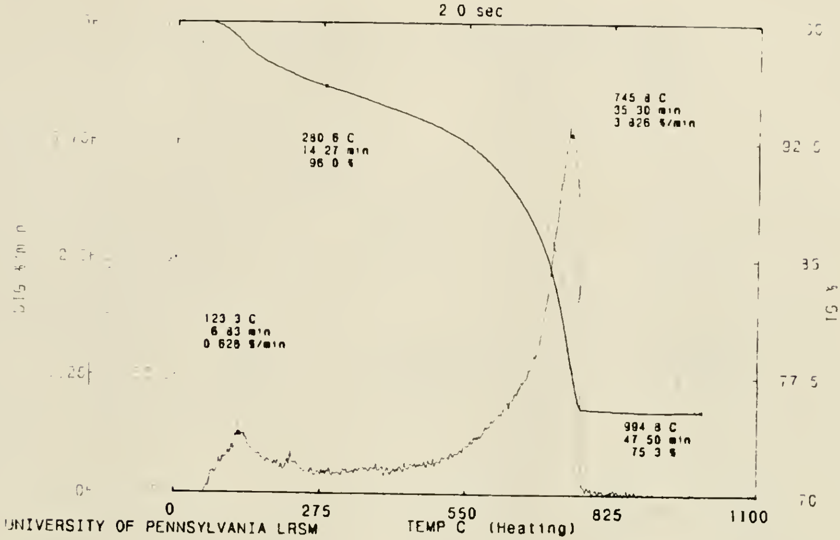
The 2nd or finish layer has a matrix of a white paste (10YR 8/1) with heterogeneous slightly graded aggregate. The aggregate is predominantly translucent subangular and subrounded grains with some amber subrounded grains. The paste contains a small amount of red and orange colored fines. This layer is even and distinct and measures 2 mm in width.

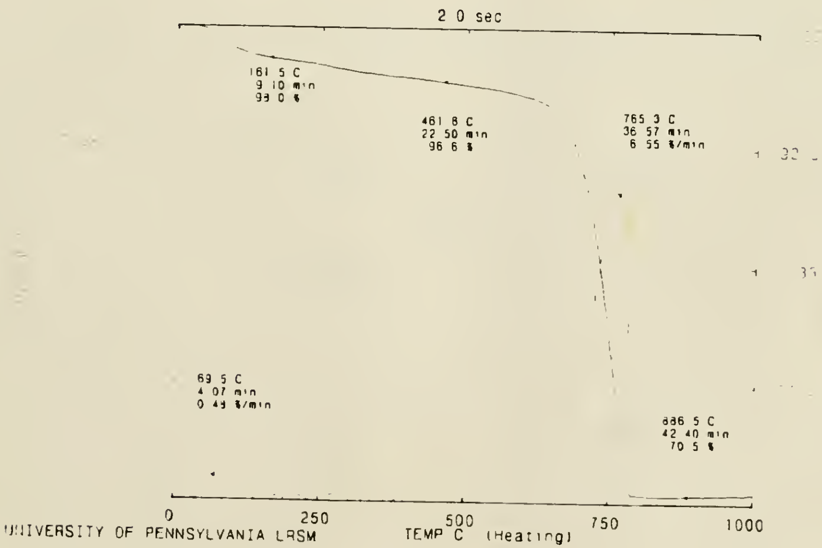


Camera Ocular: 2.5 | Microscope Objective: 1 | Total Magnification: 2.5x
Photomicrograph taken by: James Banta | Film: Ektar | ASA: 100 | Filters: daylight

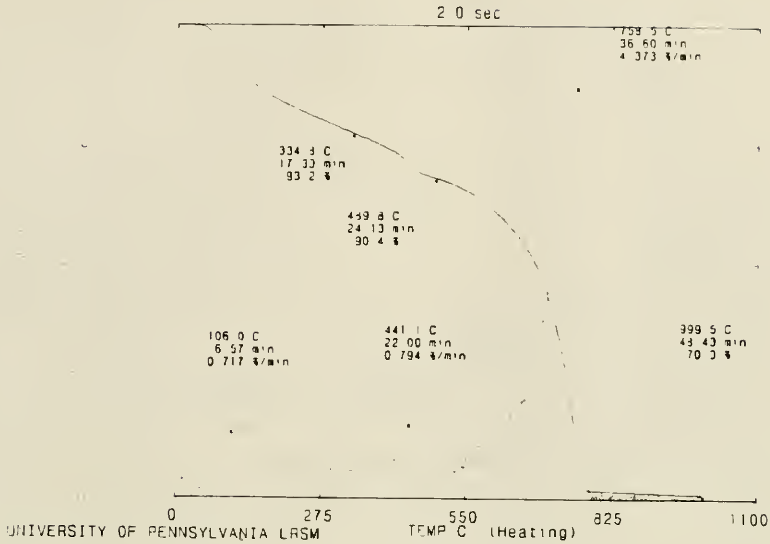
13.4. Differential Thermal Analysis Spectrograms

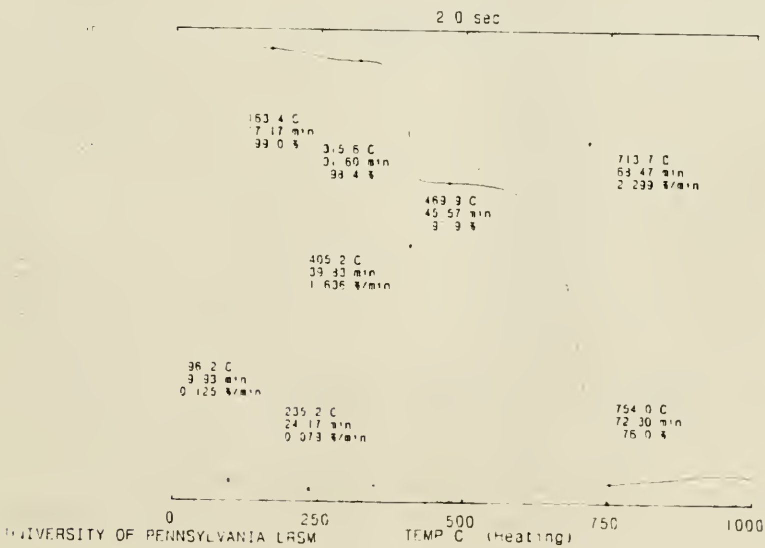
13.4.1. Sample ER 1 (top) compared with Standard for White Portland Cement and Lime (bottom)



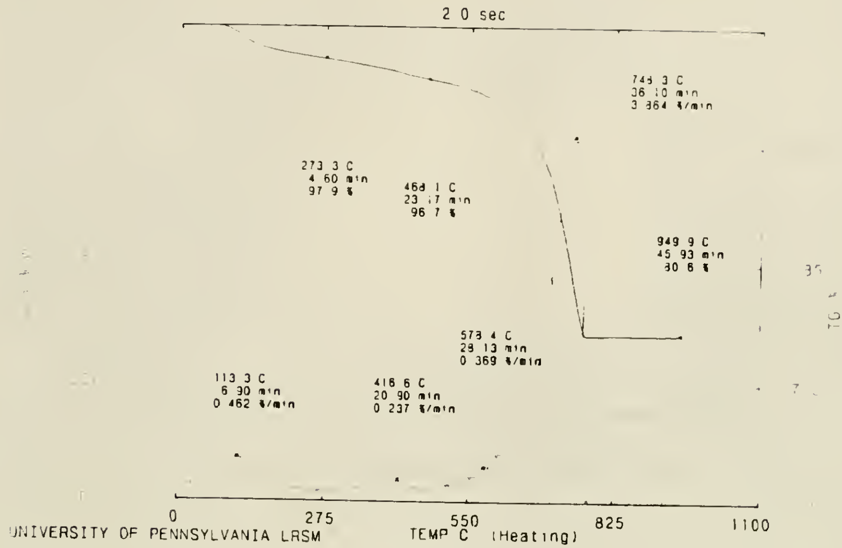


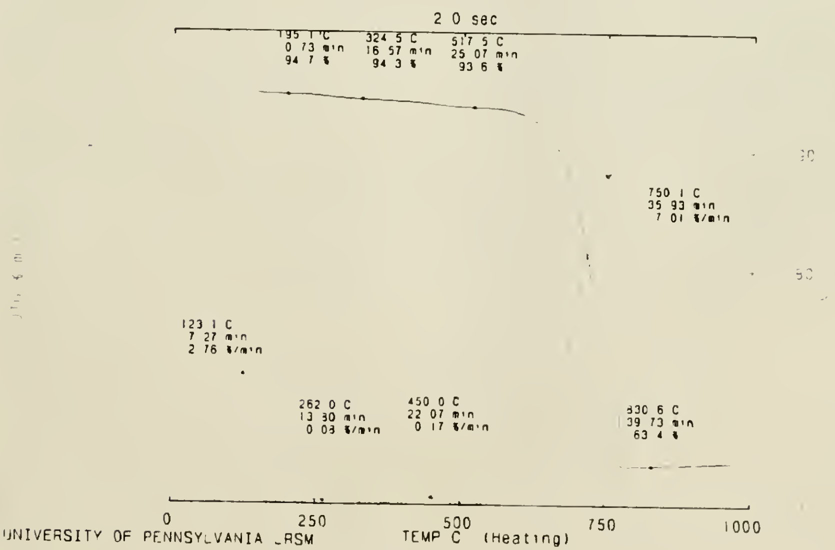
13.4.2. Sample ER 2 (top) compared with Standard for Hydraulic Lime (bottom)





13.4.3. Sample ER 28 (top) compared with Standard for Lime and Gypsum (bottom)





13.5. General Specifications for Construction by the Architectural Contractors, Lanus y Hary


PROPIETARIO
CONTRATISTA
LANÚS Y HARY
INGENIEROS CIVILES
Y
ARQUITECTOS

pared por mas de 24 horas, se retirará la hilada superior y volverá á colocar sobre un lecho de mortero fresco. Toda trabazón de mampostería vieja con mampostería nueva, se hará con todo esmero, limpiando y regando abundantemente la superficie de contacto. Los ladrillos se apoyarán sobre un espeso lecho de mortero y se les apretará hasta que la mezcla refluya por todas las juntas. Las juntas verticales se rellenarán cuidadosamente con el canto de la cuchara de modo á obtener mampostería maciza. Ningun ladrillo en los ángulos, mochetas salientes, etc., se colocará con menos de 7 centímetros de cola. Las hiladas serán perfectamente horizontales y el cordel desde el fondo de los cimientos. En caso de haber pequeñas diferencias de nivel, estas se rescatarán por hiladas de baldosas, pues en ningún caso se admitirán juntas de espesor superior á 8 milímetros. Si no hay razon de fuerza mayor, todos los muros se levantarán simultaneamente para que su asiento sea regular. En el paramento de guia de los muros de ladrillo, no se permitirán irregularidades de plana superiores á 1,2 centímetro. En el paramento opuesto se tolerará hasta 1 centímetro medido á partir del plano rasante de las irregularidades mas salientes. Los muros se levantarán rigurosamente á plomo y con una trabazón perfecta. Todas las molduras y perfiles se harán con ladrillos convenientemente tallados y queda prohibido el recurrir á clavos, alambres y otros expedientes para suplir á un olvido ó error. Queda así mismo prohibido llenar huecos y agujeros de andamio, etc., con ripio y basuras, esas partes se llenarán con ladrillo nuevo, y cortado á la dimensión requerida. Los tabiques y paredes muy altas, se apuntalarán con toda solidez mientras no hayan recibido la carga ó trabazón destinada á asegurarlos definitivamente.

Medianeras. — Será por cuenta del Constructor la ejecución de las paredes medianeras que no estuviesen en las condiciones exijidas por las ordenanzas municipales. Asimismo, deberá calzar con todas las precauciones debidas, las que no lleguen á la profundidad exijida por los planos ó la naturaleza del terreno. Será por cuenta del contratista el cierre de las casas linderas con tablas y arpilleras, la rápida elevación de las nuevas paredes, el restaurado de las habitaciones vecinas y en general toda indemnización, trabajo material, tramitación que pueda ocasionar este arreglo. Únicamente abonará el propietario los derechos de medianería que fuese necesario pagar.

Mosaicos. — Serán de marca, procedencia y precio por metro cuadrado (sin colocación) que en cada caso se fijará. Las partes que los constituye será homogénea y exclusivamente aglomerada con cemento. La capa de cemento del paramento superior tendrá un espesor de 5 mm. perfectamente ligada al cuerpo de la baldosa. La cara vista, será perfectamente plana, lisa y suave al tacto, color vivo y uniforme y dibujo; libre de mellas y rebabas.

Morteros (*Mezclas*). — Todas se dosarán en cajones ó carretillas ad-hoc de acuerdo con las proporciones é instrucciones que á continuación se enumeran. Se amasarán sobre canchas impermeables abrigadas del sol y la lluvia. Cuando el consumo diario sea superior á 10 metros cúbicos, se exigirá que la elaboración se haga en malaxadores. En la elaboración á mano de los morteros, se empezará por mezclar *sin adición de agua* los elementos constitutivos del mortero y recien se agregará agua cuando la parte obtenida sea homogenea de color. Los morteros de cemento y cal hidráulica con arena, se harán mezclando los materiales en seco y regándolos despues convenientemente. Todas las mezclas se harán de consistencia plastica. Los morteros tendrán que usarse dentro de las 18 á 24 horas despues de elaborados, pasado cuyo tiempo, serán considerados como inservibles y por tanto rechazados, no admitiéndose, que se pretenda utilizarlos con nuevas adiciones de agua y nuevo amasado. Las mezclas hidraulicas ó de fragüe rapido se harán en el instante mismo de su elaboración. Se usarán las proporciones siguientes para las mezclas:

Cal azul, pasta firme, 1 parte		A (paredes)
Arena Oriental, 1 »		
Polvo de ladrillo, 1 »		
Cal de Cordoba, en pasta firme, 1 p.		B (Rehoques interiores)
Arena oriental, 1 »		
Polvo de ladrillo 1 »		

C Mezcla B á la que se agrega 100 k. Portland p. m³
D » B » » » 150 » » »

E Mezcla B á la que se agrega 200 k. portland p. m³

F (Imitacion piedra)	Arena oriental, 3 partes
	Cemento, 1 »
	Tierra Romana, 1 »

Colorante que sea necesario y cemento blanco.

G (concreto)	Arena oriental, 2 partes.
	Cemento Portland, 1 parte.

Polvo de ladrillo. — Será de ladrillo puro y deberá reunir todas las condiciones de una buena puzolana artificial. En el caso de que se acepte polvo de escombros, serán ellos traidos al molino y únicamente molidas aquellas partes que acepten los Arquitectos.

Reboques. — En ningun caso, se rebocarán paredes que no hayan asentado completamente. Antes de aplicar la mezcla, se harán los siguientes preparativos: 1º retoque de las juntas, limpiando estas perfectamente; 2º limpieza perfecta de la pared para dejar viva la superficie de los ladrillos; 3º abrevado de

13.6. Cement Advertisement from *Revista De Arquitectura*, Buenos Aires, c. 1918

Monsieur de ERRAZURIS   DEVIS du 26 Avril 1912

RECAPITULATION

A	GROUPES PIERRE Frs (pris à Paris)	19.900 .-
B	COLONNES (prises à Paris)	32.800 .-
C	ARCHITRAVE ET FRISE AU DESSUS	11.000 .-
D	CORNICHE DU FRONTON	24.800 .-
E	FRONTON (pris à Paris)	27.000 .-
F	PILASTRES (pris à Paris)	11.000 .-
G	ARCHITRAVE ET FRISE AU DESSUS	11.000 .-
H	LA CORNICHE .... "	15.400 .-
I	COLONNES DESCENTE A COUVERT (Prises à Paris)	13.800 .-
J	L' ENTABLEMENT AU DESSUS	27.000 .-
K	PERRON ENTRE COLONNES	8.800 .-
L	PIERRE DU PERRON SUR JARDIN ET SES BALUSTRADES	42.600 .-
M	APPUIS DE BAIES 1er Etage	9.600 .-
N	BALUSTRADES DES BAIES DU REZ DE CHAUSSEE	26.000 .-
	MODELES (pris à Paris)	12.700 .-
	TRANSPORT ET EMBALLAGE DES FOURNITURES PRISES A PARIS (A B E F I) Frs	26.000 .-
		319.400 .-

13.8. Sample List

SAMPLE LIST: Palacio Errazuriz, Buenos Aires, Argentina			
SAMPLE#	IDENTITY	MATERIAL	FACADE
ER 1	Rosette under cornice, proper right	Cast W	East (P. Lucena)
ER 2	Cornice console (bracket), center	Cast Y	"
ER 3a	Cornice edge, proper left	Stucco	"
ER 3b	Balustrade above cornice, center	Cast Z	"
ER 4a	Bracket under "oeil de boeuf", p. right	Cast X	"
ER 4b	Bracket under "oeil de boeuf", p. right	Cast X	"
ER 5	Garland over central window	Cast Y	"
ER 6	Garland over "oeil de boeuf", p. left	Cast Y	"
ER 7	Swag, 2nd story, proper right	Cast Y	"
ER 8	Balcony, proper right	Limestone 3	"
ER 9a	Window frieze, 2nd story	Cast W	"
ER 9b	Stucco, scored, 2nd story, proper left	Stucco	"
ER 10	Triglyph under "oeil de boeuf", p. left	Cast Y	"
ER 11	Peristylum stucco, proper right	Stucco	"
ER 12	Pilaster, proper right	Limestone 1	West (Bustamante)
ER 13	Stucco, scored, 1st story, proper right	Stucco	"
ER 14	Stucco, scored, 1st story, proper left	Stucco	"
ER 15	Balustrade, proper right	Limestone 1	"
ER 16	Column Base, proper right	Limestone 1	"
ER 17	Steps, central	Limestone 2	"
ER 18a	Sculpture above cornice, proper right	Limestone 3	North (Libertador)
ER 18b	Sculpture above cornice, proper right	Limestone 3	"
ER 19	Pediment, proper right slope	Limestone 3	"
ER 20	Sculpture above cornice, proper left	Limestone 3	"
ER 21	Column, proper right	Limestone 1	"
ER 22	Scored stucco, center door	Stucco	"
ER 23	"Bahut" or socle, proper left	Limestone 3	"
ER 24	Sill, proper left	Limestone 1	"
ER 25	Ironwork Base, proper left	Limestone 2	"
ER 26	Terrace Border, proper left	Limestone 2	"
ER 27	Cast shell niche, proper right	Cast X	"
ER 28	Stucco, scored, proper left	Stucco	"
ER 29	Sculpture on Terrace, proper right	Limestone 3	"
ER 30	Balcony, 1st floor, proper left	Limestone 1	"
ER 31	Window hood, 1st floor, proper right	Cast Y	"
ER 32	Entrance Hall	Plaster of Paris	(Interior)
ER 33	Stairwell	Plaster of Paris	"
ER 34	New Wing	Stucco	North (Libertador)
ER 35	New Wing	Stucco	"
ER 36	New Wing step	Limestone 2	West (Bustamante)

Cast Stone Stucco Natural Stone

14.0. ILLUSTRATIONS

(All photographs were taken by the author unless otherwise indicated)


Illustration 1. Palacio Errazuriz, north facade (Avenida del Libertador).


Illustration 2. Palacio Errazuriz, north facade, portico.

Illustration 3. Palacio Errazuriz, north facade, portico and porch.

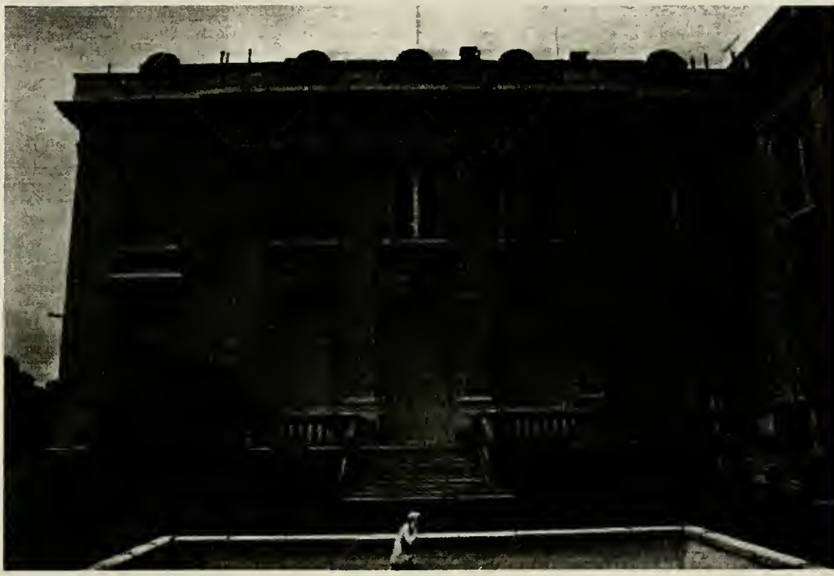


Illustration 4. Palacio Errazuriz, west facade.


Illustration 5. Palacio Errazuriz, west facade and new wing (southwest corner).


Illustration 6. Palacio Errazuriz, new wing.

Illustration 7. Palacio Errazuriz, east entrance and porte-cochere (view from the northeast).

Illustration 8. Palacio Errazuriz, east entrance and porte-cochere (view from the southeast).

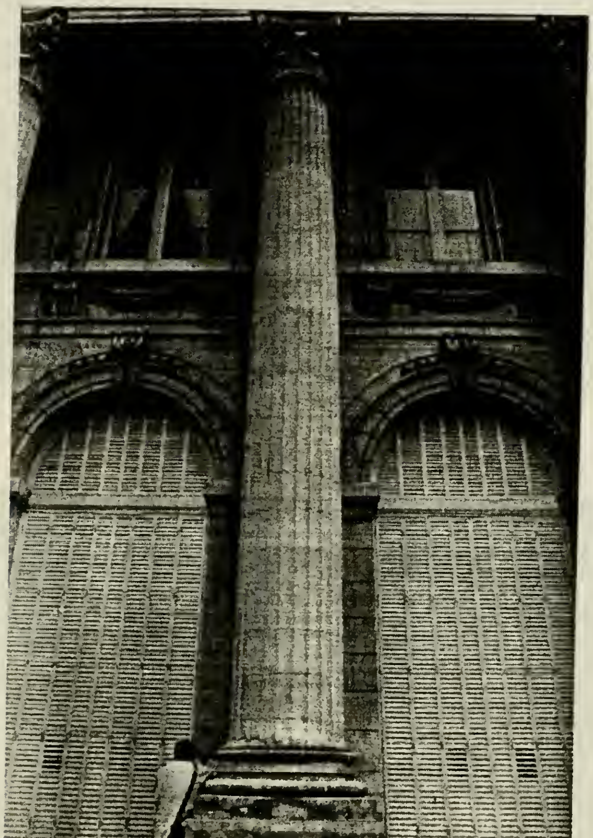


Illustration 9. Palacio Errazuriz, limestone column and base, north facade.


Illustration 10. Palacio Errazuriz, figurative sculpture, north facade.


Illustration 11. Palacio Errazuriz, limestone steps, west facade.

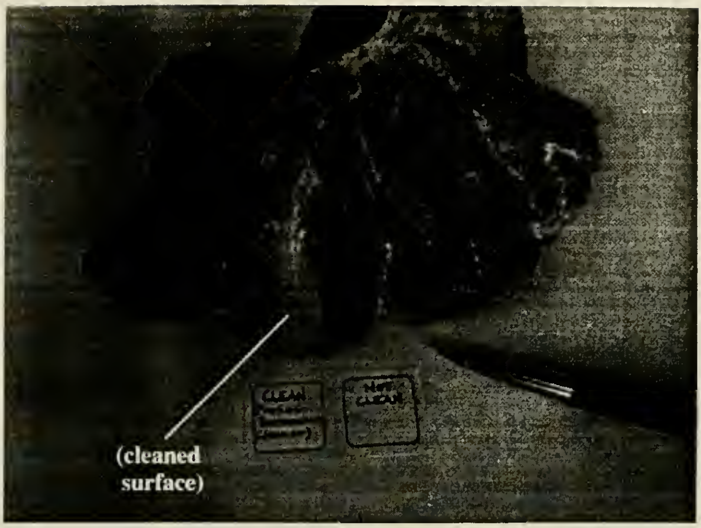


Illustration 12. Soiled cast stone cornice rosette partially cleaned with ProSoCo Heavy Duty Restoration Cleaner (1:5) showing a surface close to the original appearance.

Illustration 13. Palacio Errazuriz, limestone column; cast stone garland, swag, and triglyphs; and scored stucco (north facade). Photo by Frank Matero.

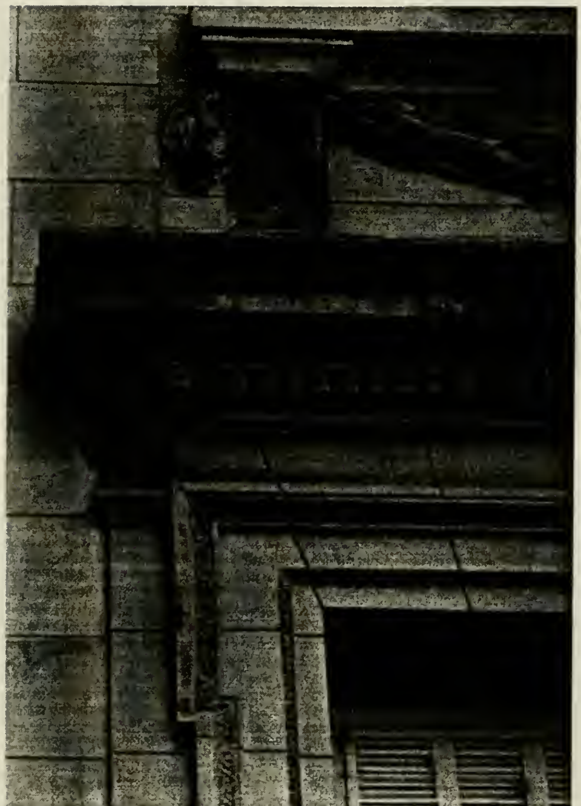


Illustration 14. Palacio Errazuriz, cast stone loss and exposed reinforcing bars, east facade. Photo by Fabio Grementieri.

Illustration 15. Atucha Residence, Buenos Aires. Designed by René Sergent, c. 1914.

Illustration 16. Palacio Bosch, Buenos Aires. Designed by René Sergent, c. 1910.

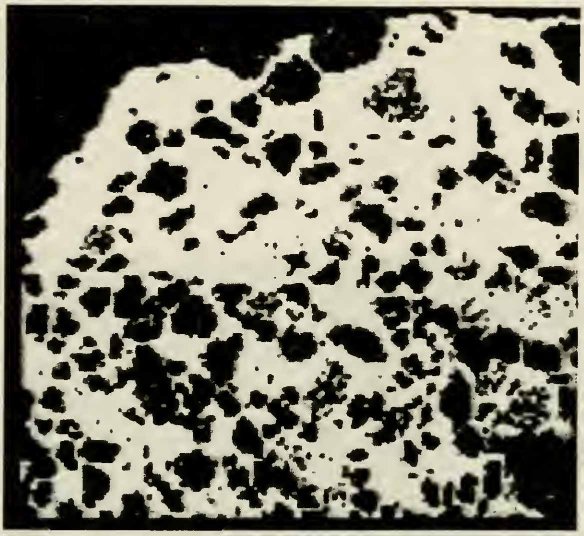


Illustration 17. Sample ER 28, SEM/EDX calcium mapping in cross section. Highlighted areas indicate calcium-rich binder paste.

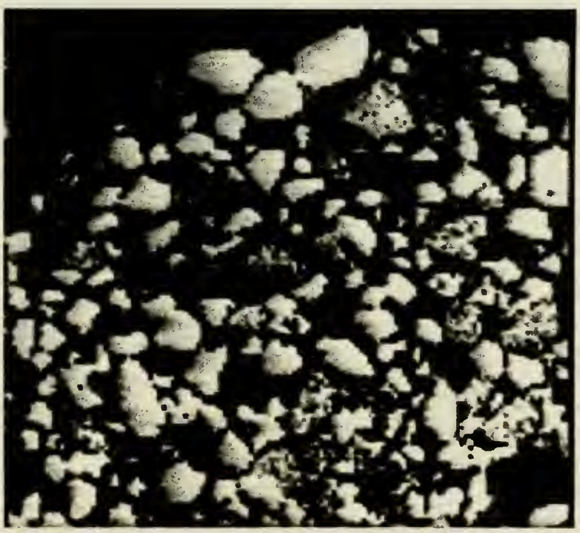


Illustration 18. Sample ER 28, SEM/EDX silicon mapping in cross section. Highlighted areas indicate silicon-rich aggregate.

Illustration 19. Sample ER 2, SEM/EDX sulfur mapping of core showing internal sulfur-rich zone suggesting the presence of a gypsum admixture.

Illustration 20. Sample ER 1, SEM/EDX back scatter electron image in cross section. Note vacuole from casting process (a), aggregate (b), and paste (c).

Illustration 21. Sample ER 1, SEM/EDX sulfur mapping in cross section showing sulfur-rich surface.

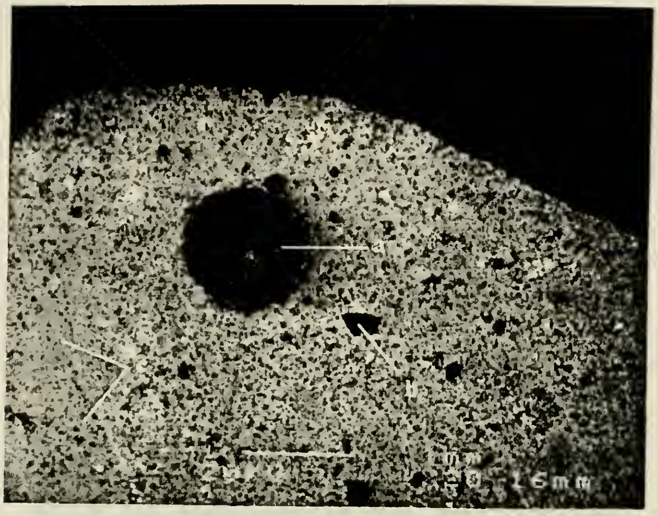


Illustration 22. Sample ER 2, SEM/EDX back scatter electron image in cross section. Note large vacuole from casting process (a), aggregate (b),and paste (c).

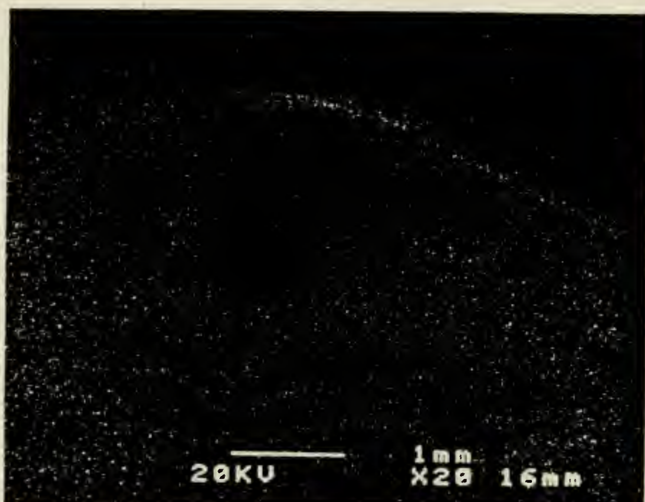


Illustration 23. Sample ER 2, SEM/EDX sulfur mapping in cross section showing sulfur-rich surface.

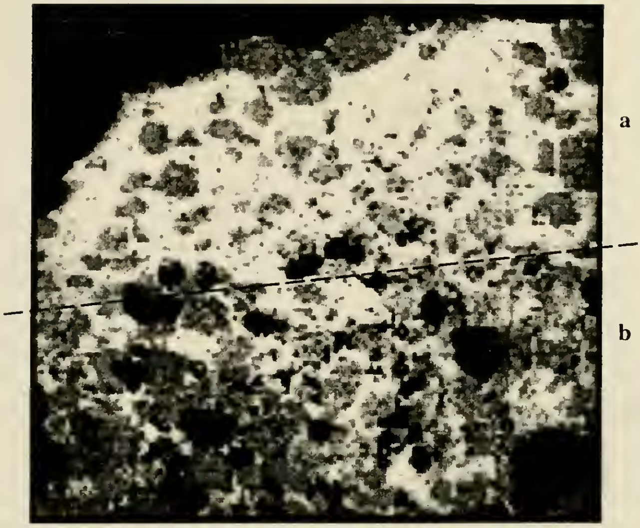


Illustration 24. Sample ER 28, SEM/EDX back scatter electron image in cross section. Note the finish layer (a) and the base coat (b) of the stucco.


Illustration 25. Sample ER 28, SEM/EDX sulfur mapping in cross section showing no sulfur-rich surface.